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Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, attending sessions at your local centre or reflecting on what you have learned and how you have learned it. Some students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 3

As the title 'The Earth and its place in the Universe' suggests, this block will be dealing with the scientific study of planet Earth. Our starting point is the place of the Earth in the Solar System, in the Milky Way Galaxy, in the Universe, but most of the block focuses in on our own planet. In particular, we will be seeking to explain its surface features, its internal structure, and the processes that we see going on around us. In comparison with Block 2, this block is centred less on a specific scientific topic or story, and is more concerned with exploring a body of knowledge and ideas associated with a broad area of science, namely astronomy and Earth science.

This exploration involves a multimedia approach to learning, as you can see from the study plan overleaf. There are three DVD-video activities, a practical work activity using the rock specimens in the practical kit, and seven DVD-multimedia activities, in addition to the work that you will have to put into studying the main text. These activities develop a range of skills associated with the scientific processes of making and interpreting observations and measurements, and with classifying and summarizing observations. As with Block 2, the non-text activities are closely integrated with study of the book, and you will benefit most if you can study them at the point that they are introduced in the book. This may well exercise your ingenuity and planning skills! However, if for some reason you are prevented from tackling a DVD-video, DVD-multimedia or practical activity at the recommended time, don't let this stop you from progressing with the book. Scan through the notes and comments for the activity in the Study File to get an idea of its content, and continue with studying the book. You won't necessarily understand everything that follows, and you will need to review the material in the book after you have had the opportunity to complete the activity, but this is better than being held up because you can't tackle a particular activity.

One place where this advice needs modifying slightly is in Section 10, which is about how seismic waves — earthquake waves — provide information about the structure of the Earth. There are three separate DVD-multimedia activities integrated into this section, and if you cannot study these when you are ready to study the section, then you may find it better to move on to Section 11, and return to Section 10 when you can tackle the DVD-multimedia activities.

As in Block 2, we have provided a set of DVD-multimedia questions to help you assess your understanding of this block. There are questions on each of the sections, and we suggest that you dip into these at intervals during your study of the block, rather than leaving them all until the end. Also provided with this block is an additional maths skills package that provides help and practice with manipulating algebraic equations, so if you are one of the many students who have a phobia about algebra from their school days, then you should set aside your phobias and half an hour of your time to study this.

There is a tutor-marked assignment (TMA 03) associated with Block 3. Since this assignment covers only Block 3, you should aim to complete it as soon as possible after you have completed your study of the block. The cut-off date by which the assignment must reach your tutor is printed on the assignment and also in the *Study Calendar*.

The study plan overleaf shows rough estimates of the times required for each section or major activity. The total minimum study time for the block — the total of the directed estimates in the study plan — is 40 hours, and this time needs to be found during the four weeks allocated to Block 3 in the *Study Calendar*. The plan shows roughly how you might split the study time over the four weeks, on the assumption that you work through Block 3 at a uniform rate.

You should begin your study of Block 3 by reading Section 1 of the book. At the end of that section there is an activity that will help you to plan your study of Block 3.

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3 The Earth and its place in the Universe

All study times are in hours

Week	Sections of Book 3	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction	$\frac{1}{2}$	
	2 The view from the Earth	$2\frac{1}{4}$	
	3 Exploring the Universe	$1\frac{3}{4}$	video $\frac{1}{4}$
	4 Newton's laws	4	
2	5 The Solar System	$1\frac{3}{4}$	
	6 The Earth's surface	$3\frac{1}{2}$	
	7 Earthquakes	2	
	8 Volcanic activity	$1\frac{1}{2}$	video $\frac{1}{2}$
	9 How rocks are formed	$2\frac{1}{4}$	$1\frac{1}{4}$
3	10 The Earth's interior	$3\frac{1}{2}$	multimedia $1\frac{1}{4}$* video $\frac{1}{4}$
	11 Continental drift: a theory for the Earth?	2	
	12 Sea-floor spreading	$3\frac{1}{2}$	multimedia $\frac{3}{4}$ multimedia $\frac{3}{4}$
4	13 The theory of plate tectonics	$3\frac{1}{4}$	multimedia $1\frac{1}{4}$
	14 Processes at plate boundaries	$3\frac{1}{4}$	
	15 Why do plates move?	$1\frac{1}{4}$	
	16 Plate tectonics and Earth history	$2\frac{1}{4}$	multimedia 1
	17 The rock cycle	$\frac{3}{4}$	
	18 The biosphere	$\frac{3}{4}$	

* This is divided into three activities

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Study File for Block 3

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Notes on activities

You should read through the notes for each activity before attempting it.

After completing an activity you should study the relevant comments in the next section of the Study File.

No estimate of time is given for activities which should take 10 minutes or less.

Activity 1.1 Planning and organizing your work for Block 3

(*You should spend about 20 minutes on this activity.*)

Now that you have completed the first two blocks of the course, you are in a good position to consider how effective your chosen ways of working are, and where you would like to make changes. There are three aspects that you might like to think about; planning your study, reviewing your study techniques, and development of skills related to using diagrams and tables.

(a) Planning and managing your study for Block 3

Spend a few minutes thinking about how you organized your study of Block 2; your notes on Activity 5.4 in Block 2 may be helpful here. You should review when and where you study — time of day or week, how long at a time, location, and so on, and should consider whether there are other options that it would be worth trying. Then draw up a study plan for Block 3 that incorporates any changes you intend to make to the way you organize your study. You will find it helpful to scan through the book and the Study File quickly to get an idea of the sort of things that are in store. Using the timetable on the bookmark for initial guidance, you should identify stages such as:

- when you intend to study each section of the block;
- when and where you intend to do the activities involving DVD-multimedia, practical work and DVD-video;
- the cut-off date for TMA 03, and when you intend to work on this assignment.

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You should refer back to your plan while studying this block, so you can keep a check on your progress. Since there are seven DVD-multimedia activities in this block, it would be worth keeping track of the time you actually spend on them.

(b) Making your learning of the science content as effective as possible

At the end of Block 2, Activity 11.1c and d asked you to reflect on the learning techniques that you have found useful, and to discuss your experience with other students. Are there any new ways of making your learning more effective that you are going to try out in this block, either arising from your own experience and reflection, or from suggestions made by other students or your tutor? Think about techniques of learning from DVD activities as well as from printed material. Make brief notes, or a list, of strategies you intend to use when studying this block, perhaps highlighting any new strategies that you intend to try.

(c) Becoming aware of the different skills that you are developing

One of the major areas of skills development tackled in this block is working with diagrams and tables. You will need to read and interpret a wide variety of maps, graphs, histograms, drawings, photographs and tables as you study this block, and you will also be asked to produce diagrams and tables of your own. These are very important skills for any scientist. There are a variety of questions and activities to help you develop and practise these skills, and they are identified alongside the relevant objectives — Objectives 29 and 32–35 on page 46 of this Study File — and we suggest that you look at these particular skills objectives now. Then keep these objectives in mind as you are doing the questions and activities.

Activity 3.1 A scale model of the Galaxy

(*The estimated time for this activity is 15 minutes.*)

Scale models are useful for helping us to visualize the very large and the very small. By choosing appropriate scales, huge objects like the Galaxy and microscopic objects like an atom can be represented by models that fit on a table top. Of course, scale models generally only represent some specific features of the real object. So a scale model of the Galaxy cannot represent the millions of individual stars, nor their relative motion, but it can convey the relative dimensions of the Galaxy more directly than numbers involving large powers of ten.

In a scale model, the sizes of all of the individual parts are reduced (or magnified) by the same amount, and this amount is often known as the scale factor (or simply the scale) of the model. To take an example, if an architect produces a scale model of a new housing development in which a house that is 7.0 m high is represented by a model that is 3.5 cm (0.035 m) high, then:

0.035 m in the model corresponds to 7.0 m in the real world

and dividing these model and real world sizes by 0.035 we see that:

$$\frac{0.035\,\text{m}}{0.035} = 1\,\text{m in the model corresponds to } \frac{7.0\,\text{m}}{0.035} = 200\,\text{m in the real world}$$

The ratio 1 : 200 is the scale of the model, and this simply means that any model distance is 200 times smaller that the corresponding real world distance. So to find the model height for a person who is 1.6 m tall, we simply divide their height by the scale factor:

$$1.6\,\text{m in the real world corresponds to } \frac{1.6\,\text{m}}{200} = 8.0 \times 10^{-3}\,\text{m, or } 8.0\,\text{mm, in the model}$$

This is exactly the same as the scale of a map. On a map that has a scale of 1 : 50 000, a distance of 5 cm corresponds to 5 cm × 50 000 = 250 000 cm, which is 2 500 m, or 2.5 km.

In this activity, you will plan scale models of the Galaxy by filling in the missing values in Tables 3.1.1 and 3.1.2.

(a) In the first scale model, the radius of the Earth will be represented by 0.100 mm, or 1.00×10^{-4} m, so the Earth in the model will be a tiny sphere 0.200 mm in diameter. The actual radius of the Earth is 6.37×10^{6} m, so
1.00×10^{-4} m in the model corresponds to 6.37×10^{6} m in the Galaxy.

(i) Use this relationship to determine the scale factor of this model.

$\frac{6.37 \times 10^{6}}{1.00 \times 10^{-4}}$

$= 6.37 \times 10^{10}$

$1 : 6.37 \times 10^{10}$

(ii) Use the scale factor you have worked out to calculate the values required to complete the third and fourth columns of Table 3.1.1. Use scientific notation for the values in metres, but don't use powers of ten when you write down the scale values in the fourth column, as it will be easier to compare the numbers if they are written out in full.

Table 3.1.1 A scale model of the Galaxy, in which the Earth's radius is 0.100 mm.

Size or distance	Actual value/m	Scale model value/m	Scale model value/mm
radius of the Earth	6.37×10^{6}	1.00×10^{-4}	0.100
radius of the Sun	6.96×10^{8}		
average distance of the Earth from the Sun	1.50×10^{11}		
distance from the Sun to the nearest star	3.99×10^{16}		

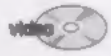
(b) In the second scale model, you should use 0.100 mm to represent the distance from the Sun to the nearest star. Complete Table 3.1.2 by first calculating the scale factor for this model, and then calculating the scale model values, in metres and in millimetres, for the three other sizes. Do not use powers of ten in the scale model values in the final column.

Table 3.1.2 A scale model of the Galaxy, in which the distance from the Sun to the nearest star is 0.100 mm.

Size or distance	Actual value/m	Scale model value/m	Scale model value/mm
distance from the Sun to the nearest star	3.99×10^{16}	1.00×10^{-4}	0.100
diameter of the globular cluster M13	1×10^{18}		
thickness of the disc of the Galaxy	2×10^{19}		
diameter of the disc of the Galaxy	1.2×10^{21}		

Study the scale model values in these two tables to get an impression of the relative sizes and distances in the Galaxy. You could try drawing some of the scale model values as lines on a piece of paper to help visualize their relative sizes.

Activity 3.2 Spiral galaxies



(*The estimated time for this activity is 15 minutes.*)

This activity consists of a DVD-video sequence containing animations which will help you to understand motions in the disc of a spiral galaxy and the existence of spiral arms. A face-on view of a simplified model of the disc of a spiral galaxy shows how the stars rotate around the galactic centre. Then the spiral arms are added, and the difference in the way that the arms and stars rotate is highlighted. The DVD-video concludes by homing in on a spiral arm, to explore star formation.

To appreciate the animations fully you will need to replay them two or three times. Therefore, even though the playing time of this sequence is only a few minutes, you will probably need to spend 10–15 minutes studying it.

'Spiral galaxies' is on DVD 1 (DVD-video sequence 225–239). You should view this now.

Note that the contrast between the density of the material within a spiral arm and the density in the rest of the disc has been exaggerated for clarity.

Activity 5.1 The giant planets

(*The estimated time for this activity is 20 minutes.*)

This activity asks you to consider two related questions. The first part asks you to explain the compositions and positions of the giant planets, and this can be answered using material from Sections 5.2 and 5.4. You should be familiar with writing a brief account like this from activities in Block 2. You need to find the relevant information, make notes and then write out an answer in about 150 words.

When you have done the first part of the activity, you should have reinforced your understanding of the theory of the origin of the Solar System. The second part of the activity asks you to apply this theory to explain something that was not explained in the text. The text describes the probable structures and the positions of the subgiant planets, but it does not explain how subgiants were formed. We are asking you to use what you have learnt to speculate on how the subgiants formed and on why they occupy the positions they do in the Solar System, beyond Jupiter and Saturn. One clue: current theory indicates that icy-rocky cores form more slowly with increasing distance from the Sun. You may be able to give a possible explanation immediately, or you may need to give the matter more thought. You may find it useful to make notes about what you know about:

- the theory of the origin of the Solar System (Section 5.4)
- the slower formation of icy-rocky cores with increasing distance from the Sun.

You need to work out a consistent hypothesis of your own that links these with the composition and positions of the giants which you wrote about in the first part of this activity. Have a go at writing this down (in about 150 words) and then look at the comments on this activity.

Activity 6.1 Describing examples of activity on planet Earth

Imagine that you are visited by an alien space traveller who is collecting information about different planets. Having identified you as a science student, and therefore a source of useful information, it asks you to compile a list of about ten moving things that illustrate that movement is commonplace on Earth. The traveller is interested only in naturally occurring things, so manufactured items such as cars and moving spacecraft should not be included. In compiling your list, try to include at least one example of a solid, a liquid and a gas. Also, try to include something(s) from the water cycle and from the carbon cycle, together with examples that are not part of the water or carbon cycles. For each entry in your list, state whether it belongs in the atmosphere, biosphere, hydrosphere, or the solid rocky part of the Earth.

Activity 6.2 A summary map of the Earth's major features

Figure 6.2.1 is a map of the world which you may find useful for locating features on the poster map or places mentioned elsewhere in the course materials. You may also wish to refer to an atlas of the world on occasions.

Figure 6.2.1 The world.

The poster map of the Earth shows a number of major features including mountain belts on the land, and mid-ocean ridges. Locate the mountain belts and mid-ocean ridges on the poster and summarize their positions by sketching them on the blank map of the Earth (Figure 6.2.2). A good approach would be to use a different colour or symbol for each type of feature (e.g. blue or dotted lines for mid-ocean ridges, brown or broken lines for mountain belts).

Figure 6.2.2 Map of the Earth.

As you work through Section 6 you will meet other features of the Earth's solid surface which you will be asked to add to your sketch map. Drawing this sketch map should help you to remember where the main features occur on the Earth's surface, and what shapes they form. It is also a good introduction to producing your own diagrams and maps, a skill that will be developed throughout this block.

At the end of Section 6.2.2

Add the ocean trenches to Figure 6.2.2.

At the end of Section 6.2.3

Add the island arcs to Figure 6.2.2. Notice which ocean trenches have neighbouring island arcs.

Activity 6.3 Describing your sketch map in writing

One of the aims of this block is to develop skills of using diagrams, maps and other visual information. Translating visual information into words (and vice versa) is an important skill in science. Your sketch map of the Earth's solid surface from Activity 6.2 gives you a visual summary of the information in Section 6.2. Now summarize in writing the information about the major features shown on your sketch map. Your piece of writing should describe any general trends in the location of important features, but you are not required to give details (or names) of the individual features. It does not have to be very long (the answer given in the Comments section is only about 100 words), but you should think about how you will structure your piece of writing to present the information in a logical order. Remember the advice on the 'three C's' (conciseness, coherence, clarity) in Block 1!

Activity 7.1 Using a newspaper report on the Kobe earthquake

The newspaper article reproduced in Figure 7.1.1 (*p. 8*), reporting the effects of the Kobe earthquake, was published on the front page of the *Guardian* on 18 January 1995, the day following the earthquake. You may encounter a lot of scientific information in news reports and other articles. Being able to identify the key points in such articles can help you to make sense of the science (and can help you to judge whether they are reliable reports).

This activity will enable you to identify some of the effects due to earthquakes. To do this, read the article and highlight or underline the text that refers to the effects.

After you have finished reading the article, make a list of the highlighted effects. You might find it useful to combine similar types of effect under a suitable heading, such as 'effect on buildings' or 'sounds'. For example, you might note 'sounds: deafening, roaring'. Your completed list will be a record of the key observations made by the eyewitness to the Kobe earthquake.

You may find SGSG *Chapter 2, Section 5 useful for this activity.*

Activity 7.2 Comparing information on different maps of the Earth

(*The estimated time for this activity is 15 minutes.*)

This activity will give you more practice in translating from diagrams to written information.

For part (a) you are asked to summarize in words the pattern of earthquakes on the Earth's surface. Remember that, as with any piece of writing, your answer should have a logical flow, and that on this occasion your writing needs to be sufficiently clear to convey the information from the map to someone who cannot see it. Start by studying Figure 7.7 in the book carefully. The way in which you structure your answer needs to be related in some way to the actual distribution of the earthquakes. Will you describe the pattern from west to east across the map, or continent by continent, or on land then at sea, or will you start by giving a short summary followed by more detailed information? Try to keep your answer within about 100 words.

For part (b) you are asked to use two world maps which look quite different because they have different scales and they use different map projections (Box 6.1). So you might start by looking for clearly recognizable features like continents that you can identify in each map, and by comparing the scales, indicated by the spacing of the lines of latitude and longitude. Once you have worked out how the two maps relate to each other, it becomes more straightforward to identify the position on one map that corresponds to a particular feature on the other map, and specifically to see how shallow and deep-focus earthquakes relate to surface features.

Activity 7.3 Investigating links between earthquake magnitude and location

You saw in Activity 7.2 that some of the Earth's surface features (the ocean trenches, mid-ocean ridges and certain mountain belts) have earthquakes associated with them, and that some of these features have both deep-focus and shallow-focus earthquakes. In this activity you will investigate whether there is also a relationship between the size of an earthquake and its location relative to the major surface features.

(a) Study Figure 7.7, and for each of the surface features (i), (ii) and (iii) listed below, decide what is the highest earthquake magnitude (on the Richter scale) usually associated with the feature. Ignore any larger-magnitude earthquakes that occur very infrequently.

(i) Mountains and ocean trenches surrounding the Pacific Ocean.

City consumed by flames

An awesome shudder like the end of the world

Eyewitness

Dennis Kessler in Kobe

The suddenness with which the earthquake struck was almost cruel. One moment we were fast asleep, an instant later the floor — the entire building — had turned to jelly. But this is no gently undulating, liquid motion. This is jarring, gut-wrenching shuddering of awesome proportions. It is impossible to think straight.

You are in bed, the safest place in the world. Your bed is on the floor, what you used to think of as solid ground. And with no warning the world has turned into a sickening roller-coaster ride, and you want to get off.

Possibly the most frightening part is the sound. This is not the dull rumble of thunder. This is a deafening, roaring sound, coming from everywhere and nowhere, and it sounds like the end of the world. It is terrifying.

Then you take in the other sound effects: books toppling off shelves, glasses and crockery smashing, pictures crashing to the ground. You realise the horrendous creaking all around you is the building you're in; walls, ceilings and floors looking and feeling as if they're not just breathing, but hyperventilating. Everything is rattling and shaking.

Suddenly you're very aware of the six storeys of other apartments right above your head. You shouldn't be sitting up in bed thinking about what to do. Just like all the children are taught in Japanese schools, you should grab some clothes and get the hell out.

But that assumes you're reacting rationally and decisively, that your thought processes are of an order greater than those of a frightened rabbit. Instead you run out of your bedroom and stare open-mouthed at your flatmates, who have just done the same. It's an earthquake, we all blurt out. But there shouldn't be an earthquake in west Japan; everyone knows it's not an earthquake prone zone, unlike Tokyo.

So far this has all taken about 15 seconds. Thirty seconds later we're dressed and out the door, but by then the shaking has faded into nauseating swaying, and the loudest sound is the pounding of my heart in my ears. With the sun beginning to rise, a quick walk around the block confirms that there is no damage to survey. No one else is on the street, no signs of life.

Then the aftershocks start, one after another. At 6.30am, 45 minutes after the quake, every television channel has a bleary-eyed, unshaven announcer presenting the first accounts of damage. Every television station has a video camera permanently recording in its newsroom, just to capture the moment a quake might hit. The scenes we are shown are unbelievable: a massive shudder striking like a bomb blast, except it goes on and on; chairs, filing cabinets, lights, books — everything that can move, does.

So far we're still in shock, only just able to start laughing it off. Maybe everyone else was as lucky as we have been. Then the reports of damage start coming in; of the fires raging throughout Kobe, of the houses that have collapsed. Then the first helicopter footage showing the modern, elevated expressways that have toppled over; the trains derailed, tracks bent like wire. And then, inevitably, news of the death toll: first 60, then 74, then 104, then over 200. Twelve hours after the earthquake, the official death toll is over 1,000 and rising.

An expert assures us that further large tremors can be expected, and that many buildings that appear to have withstood the quake may have been severely weakened and not up to dealing with another.

What is certain is that I, like many others, will be sleeping fully clothed and very lightly tonight. And I will never again use the phrase "safe as houses".

Dennis Kessler is a freelance journalist living in Japan

Figure 7.1.1 From the *Guardian*, Wednesday January 18 1995.

(ii) Mountain belts in Europe, mountain belts in Asia.

(iii) Mid-ocean ridges.

(b) Now fill in Table 7.3.1, using your answers from part (a) of this activity and the answer to Activity 7.2. The completed table will provide a summary of the relationship between earthquake depth, size and location.

Table 7.3.1 The depths and sizes of earthquakes at different locations

	Mountains and ocean trenches surrounding the Pacific	Mountain belts		Mid-ocean ridges
		Europe	Asia	
depth (shallow-focus, intermediate-focus, or deep-focus)	All	Shallow foci	Shallow foci	Shallow foci
largest magnitude (up to magnitude 7.9, or over magnitude 8.0)	8+	7.9-7.9	7+	

Note that if you have Internet access, you can examine other earthquake data in the British Geological Survey World Seismicity Database web site: http://www.gsrg.nmh.ac.uk

Activity 8.1 Observing, classifying and explaining volcanic eruptions

video

(*You should spend no more than about 30 minutes on this activity.*)

The DVD-video 'Volcanoes' shows eruptions from a number of volcanoes around the world (Table 8.1.1 and Figure 8.1.1, on p. 10). By studying the DVD-video you will learn what these phenomena look like, what processes cause them and what hazards they pose. The activity will also give you practice in making observations and in classifying natural phenomena.

Table 8.1.1 Volcanoes with eruptions identified by DVD-video timing numbers in the DVD-video 'Volcanoes'. (These timing numbers are referred to as 'page numbers' in the DVD-video narration.)

DVD-video timing numbers	Volcano
248–265	Mauna Loa and Kilauea (Hawaii, USA)
267–268	Etna (Sicily)
274–275	Galunggung (Java, Indonesia)
277–281	Pinatubo (Philippines)
281–283	Mount St Helens (Washington, USA)
284–291	Unzen (Kyushu, Japan)
292–295	Augustine (Alaska, USA)
298–300	Etna (Sicily)
300–301	Kilauea (Hawaii, USA)
304–305	El Chichon (Mexico)
305–307	Soufriere Hills (Montserrat)

Volcanic eruptions can be complex, but the number of basic behaviours is quite small so a simple classification scheme can usefully summarize them. We have selected examples that illustrate three basic volcanic eruption styles, and in order of appearance these are:

- eruptions producing lava flows (i.e. effusive eruptions),
- eruptions producing very tall plumes or columns of ash and gas (a type of explosive eruption);
- eruptions producing pyroclastic flows (a type of explosive eruption).

There are cases where conditions conspire to produce eruptions somewhat different from the examples contained in the DVD-video. So do not be surprised if you encounter a news report of an eruption which does not match exactly the examples shown here.

The volcanoes and eruptions shown in the DVD-video are identified by numbers, which are keyed to the information in Table 8.1.1 and Figure 8.1.1. This information is not critical to completing this activity, although when you return to Book 3 you will consider the geographic distribution of volcanoes with different types of eruptions.

We suggest you watch the DVD-video twice; first, watch it all the way through to see the full range of phenomena, making comparisons and contrasts more obvious; then watch it a second time while carrying out the following two tasks.

Task 1

Summarize information and observations from the DVD-video in Table 8.1.2.

Task 2

Summarize the main features of the three styles of eruption by drawing labelled sketches of each of them

'Volcanoes' is on DVD 1 (DVD-video sequence 240–313). You should view this now

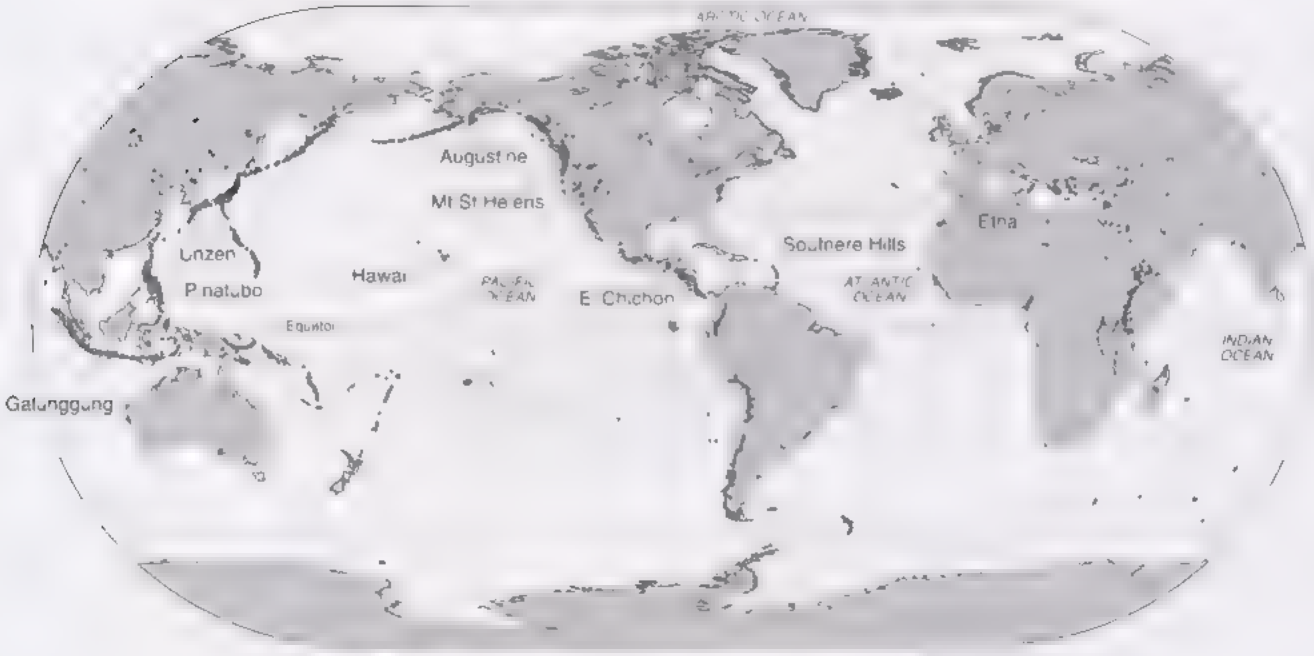


Figure 8.1.1 Locations of volcanoes shown in the DVD-video 'Volcanoes'.

Table 8.1.2 A summary of common volcanic eruption styles, their causes and their effects.

Eruption style	Description	Examples of volcanoes with this type of eruption	Causes and processes	Effects and hazards
lava flow				
eruption column				
pyroclastic flow				

Activity 9.1 An introduction to rocks and their origins

(*The estimated time for this activity is 1¼ hours.*)

Equipment

KIT ITEMS
Rocks and mineral specimens 1–6 (see Figure 9.1.1)
Hand lens

NON-KIT ITEMS
Ruler (marked in millimetres)
Vinegar (optional, for Task 4)
Old jam jar (optional, for Task 4)

Aims

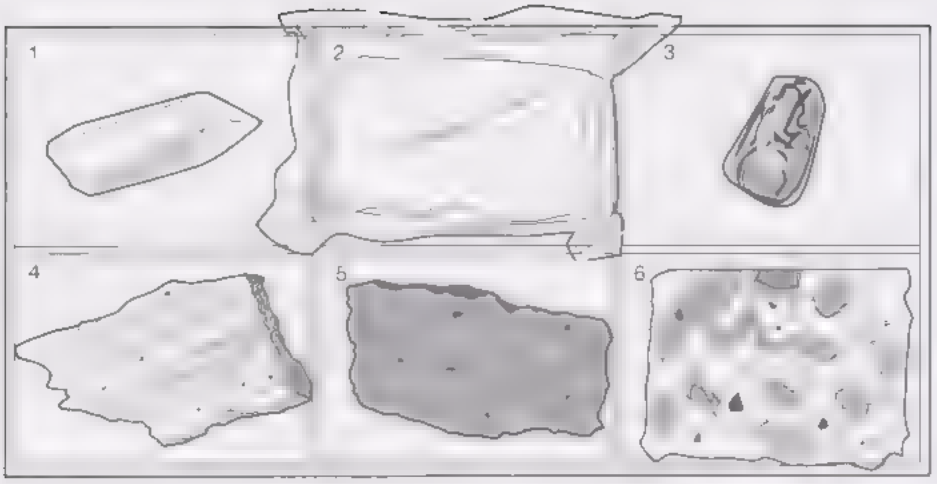
1 To examine a number of rock specimens, and to link observations of the specimens to the processes that formed them.

2 To develop practical science skills associated with making observations and recording information.

Introduction

Rocks are formed by different geological processes on the Earth, and in this activity you will examine a number of rock specimens and will discover that their features contain clues to the processes that formed them. This will involve first making observations and then interpreting the observed features in terms of the processes by which rocks are formed.

You will have been sent a Practical Kit, packed in a box with a clear plastic lid. The Practical Work Booklet contains instructions for identifying and labelling the rock and mineral specimens and the fossil replicas in the kit; if you have not yet labelled your specimens you should do so now. A key to the rock and mineral specimens in the kit is reproduced here as Figure 9.1.1.



key to specimens

1 colourless, transparent	2 pale, in plastic bag	3 polished pebble
4 grey, with shiny surfaces	5 very dark	6 pale, with dark patches

Figure 9.1.1 Key to the rock and mineral specimens in the Practical Kit.

For this activity you will need the hand lens and the six specimens labelled 1 to 6. Geologists call these 'hand specimens' because they are the right size to be examined in the hand, in contrast to examining a large outcrop of rock in a cliff or crag.

Each rock specimen is unique, so if you compare your example of Specimen 2, say, with those of other students it is likely that you'll be able to see subtle differences in perhaps grain size or colour, even though the specimens are all of the same rock, taken from the same rock outcrop.

Specimens 2, 4, 5 and 6 have been prepared by sawing up larger broken samples taken from rock outcrops, so they have at least one flat sawn surface, as well as rough, naturally broken, surfaces. In some cases the sawn surfaces may have curved markings over them — this is just an effect of the sawing process and is not a characteristic feature of the rocks themselves, so please ignore any of these curved marks. Also, Specimens 4 and 5 can have brown or orange surface stains, caused by chemical alteration of the rock after it formed, and these should be ignored too. The features on sawn surfaces can often be enhanced by wetting the surface with some water.

Practical procedure

Using the hand lens

Before starting to examine the specimens, take a little time to familiarize yourself with using the hand lens. It comprises two magnifying lenses, each of the same power (magnification of × 4). You can use just one lens or, to achieve a higher magnification (× 8) and see more detail, you can use both lenses together. The correct way to examine objects with a hand lens is shown in Figure 9.1.2. Some additional useful hints are:

- Hold the hand lens 2–3 cm from your eye and bring the specimen up towards the lens until it is in focus
- Make sure the surface of the specimen is well lit from the side.
- Keep the hand lens and the specimen surface parallel to each other and hold both steady.
- With rough surfaces you have to move the specimen up and down to bring different parts into focus

You might like to practise using the hand lens by looking at the end of one of your fingers, or the millimetre divisions on a ruler. How many ridges on your fingertip are there to a millimetre?

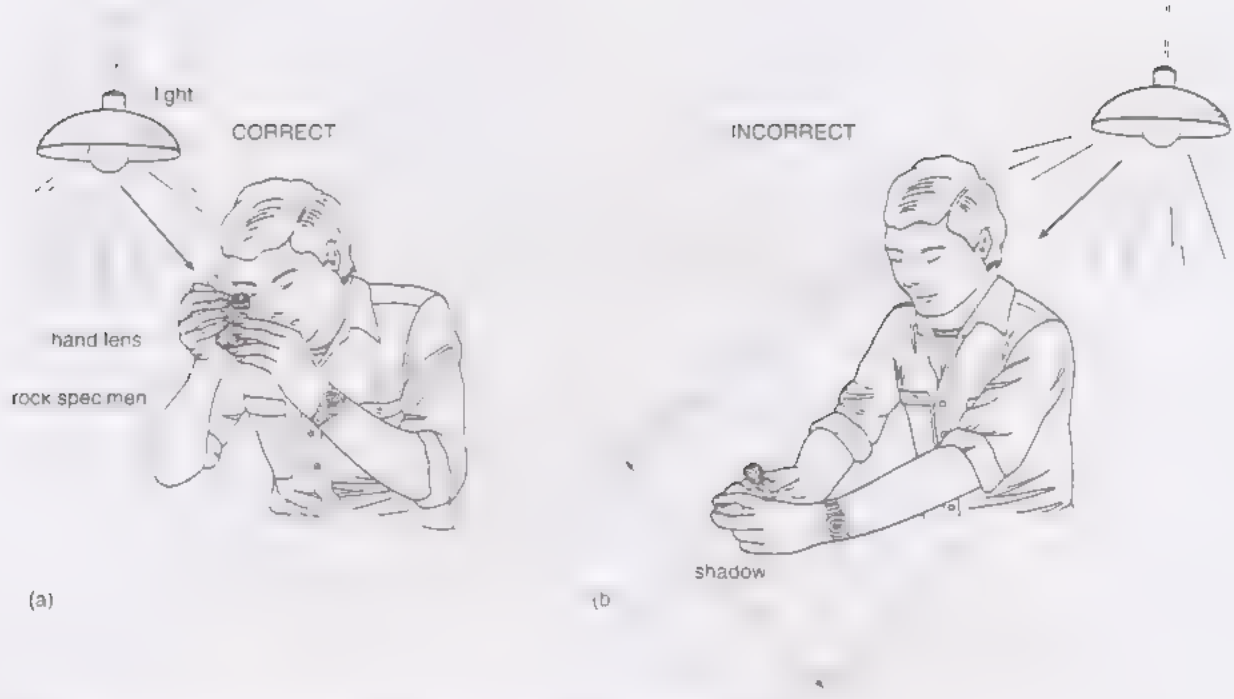


Figure 9.1.2 (a) The correct use of the hand lens. (b) Incorrect use of the hand lens

Task 1 A preliminary classification of the specimens

The six specimens labelled 1 to 6 from the Practical Kit are all different, but some share common features. Take a few minutes to look carefully at the six specimens (you do not need to use a hand lens at this stage) and decide how you might divide the specimens into groups based on similarities and differences. ◀

If you thought that there were several possible ways of dividing the six specimens then you'd be right. You could divide them based on whether they are light or dark in colour, or whether they have shiny or rough surfaces; these are just two of the possible ways of dividing or classifying the specimens based on their appearance. However, perhaps the most obvious division is between Specimen 1 and all of the others. Unlike the others, Specimen 1 has a regular shape and is transparent or faintly cloudy in appearance, and its surface has a glassy sheen or lustre. The others are opaque, have irregular shapes and contain patches with different colours. These differences single out Specimen 1 as a crystal of a *mineral*, whereas the others are aggregates of different mineral grains, in other words rocks.

Specimen 1 is a crystal of the mineral *quartz*. Some of the rock specimens have flat, cut sides but the quartz specimen is uncut and unpolished — this specimen occurs naturally like this. Quartz is a mineral composed of silicon and oxygen atoms arranged in a regular way, and it is this that gives the crystal such a regular shape. Quartz is one of the commonest minerals on the Earth. (You will learn more about minerals in Block 10.)

We are now left with five rock specimens. In order to find out more about the different origins of these rocks, we need to examine them more closely. We'll start with Specimen 2.

Task 2 Making observations of Specimen 2

Take Specimen 2 out of its protective bag and examine closely both the flat sawn surfaces and the natural broken surfaces. Feel its surface with your fingers, look at the rock close up and through your hand lens.

- What colour is the specimen?
- Are its broken surfaces rough or smooth?
- How large are the individual grains that make up the rock? (Use your hand lens and a ruler to estimate the average grain size.)
- Look more closely at the individual grains and at the joins between the grains, using the hand lens. Do you think the grains interlock as though they grew together, or do they look more like individual fragments which have become stuck together? ◀

Your observations should have enabled you to decide that the specimen is made of small grains or fragments of a pale material, typically 1–4 mm in size, and that these grains are stuck together to form a rock with a rough surface. If you are not sure, look again at the specimen through your hand lens. Notice that many of the grains have rounded or broken corners, indicating that they are fragments broken from larger pieces of material. The form of the grains that a rock is made of, and how they are arranged together, is called by Earth scientists the rock's *texture*. This rock has a *fragmental texture*, meaning that it is composed of broken fragments of various materials.

We have provided a table for you (*opposite*) to record your observations and other information about the rock specimens. You can now fill in details of the texture, colour and grain size in the 'Specimen 2' row in Table 9.1.1.

Interpreting Specimen 2

The texture of a rock contains important evidence about the processes that formed the rock. Most of the larger fragments in this rock are fragments of quartz — the same material as Specimen 1. You may be able to see this by examining some of the grains closely; the glassy, broken surfaces are similar to the glassy, broken surfaces of Specimen 1. So how can we use this information to interpret the origin of this rock specimen?

Where might you see many small grains of quartz like those in this specimen today?

On a sandy beach or river bed.

So, where do you think that these quartz fragments, and the other grains that make up the rock, came together?

In an ancient beach or river bed.

The rock formed by the accumulation of sand grains, hence it is called *sandstone*. The sand grains were deposited and then buried under more layers of sand. Over a very long period water would have percolated through the deeply buried and compacted sand, slowly depositing fine particles called cement which stuck the original grains together. By this process the loose sand has been hardened, or *lithified*, into solid rock. The larger grains are only loosely held together (cemented) by the much finer grains, and they are easy to dislodge with a penknife.

The quartz grains in this rock have had a long history of buffeting and breakage to produce the somewhat rounded shape of each grain, and this buffeting would have taken place by collisions with other rocks and mineral grains during each grain's journey down a river or along a shore to its final resting place. (Specimen 2 was collected in Yorkshire.) Rock and mineral fragments that are transported and deposited in this way, by water, wind or ice, are called sediments (Block 2, Section 3). The sandstone formed by accumulation of sedimentary grains, so it is a **sedimentary rock**.

You may be able to see layers of different grain size in your sandstone specimen. These are original layers, formed when sediment particles of different sizes accumulated.

Now complete the 'Specimen 2' row of Table 9.1.1 by filling in the remaining columns.

Table 9.1.1 Observations and interpretations of rock specimens

Specimen number	Texture	Colour(s)	Typical grain size(s)	Rock type (metamorphic, sedimentary or igneous)	Process of formation	Rock name	Additional comments
2							
3	Smooth	Dark Blk					
4		grey					
5							
6							

Task 3 Observation of Specimen 3

Specimen 3 is particularly attractive to look at because it has been polished so as to enhance the features it displays. Examine it closely and decide on its colour and grain size, as you did for Specimen 2.

- Colour:
- Grain size mm:

You may have found this rather difficult, because the specimen does not look similar all over; there are different types of material to be seen. Some of the rock is made of a dark grey, almost black, fine-grained material (the grains are too fine to distinguish individually, even with a hand lens). This is known as the rock's matrix. Set within the matrix are some intriguing pale grey, brown or pinkish objects, most of which are a few mm in size.

- What shapes are these pale objects?
- Does this rock have a fragmental texture (i.e. is it composed of broken fragments)? ◀

From your examination of Specimen 3 you should have concluded that the rock contains a lot of pale-coloured, broken fragments (do not be confused by the smooth surface, which is the result of polishing).

Some of the pale-coloured objects are circular and sometimes have a circular or star-shaped 'hole' at their centre. Others are elongate, sometimes with a faint but evenly-spaced banding effect. Still others have broken edges. And the smaller ones look as if they are broken fragments of larger pieces. So this is another fragmental rock, and it is therefore another example of a sedimentary rock.

Interpreting Specimen 3

So what are the pale-coloured objects in this rock? You might be able to get a feel for their three-dimensional shape by turning the specimen to see edge-on and side-on views of the same object. This will confirm that some of the larger fragments are actually cylinders. On a flat surface you sometimes see their circular cross-section and sometimes you see a longitudinal view.

Given the information that this rock formed under the sea, can you suggest an origin for these regular-shaped fragments? (*Hint.* What might fall to the sea-bed and be incorporated into the sediment?)

They are fragments of marine organisms.

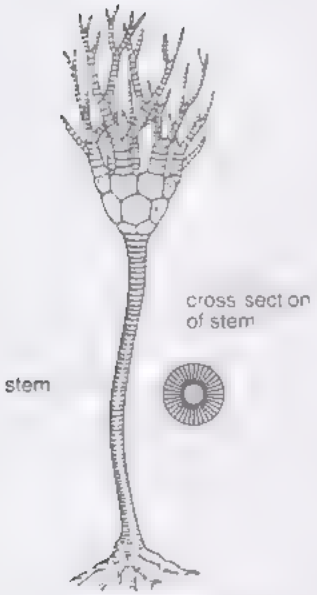


Figure 9.1.3 Reconstruction of a fossil crinoid

These pale objects are fragments of organisms called crinoids, sometimes called 'sea lilies', and you can see a reconstruction of them during life in Figure 9.1.3. Crinoids look rather like plants but are actually animals and are relatives of sea-urchins and starfish. They live in clear, shallow seas. The fragments in Specimen 3 are parts of broken stems and other parts of the animal. They are fossil remnants of former life. So the texture and composition of this rock enable us to interpret it as a sedimentary rock, formed when crinoid fragments were laid down together with dark-coloured mud as layers at the bottom of a clear, shallow sea. The individual mud particles are too tiny to be distinguished, even with the hand lens. The fossil crinoid fragments are made of calcite — calcium carbonate. Hence this sedimentary rock is a type of *limestone* (Block 2, Section 8).

Task 4 The acid test (optional)

> *Warning:* This optional test will remove some of the polished surface from your specimen.

One way of confirming that the fossils in this rock are indeed made of calcite is to place the specimen in an old jam jar with a small amount of vinegar, which is a weak acid. Use enough vinegar to cover about half the specimen. Replace the lid on the jar, label the jar clearly 'NOT TO BE EATEN' and put it somewhere out of the reach of children where it will not be knocked over.

The acid will react with the calcium carbonate, dissolving it away and liberating carbon dioxide gas. You may be able to see bubbles of carbon dioxide around the specimen. To get much of an effect you will need to leave the specimen standing in vinegar for about 4 hours, or overnight; after this time take the rock specimen out of the jar and wash it under the tap. The acid treatment will remove the shiny polished surface from the rock

and will dissolve away some of the fossil material, leaving the muddy matrix standing slightly proud of the fossil material. The muddy material in the matrix does not react with the acid. With your hand lens, you may be able to see that the matrix has become slightly pitted, indicating that it contained small amounts of tiny calcite fragments that have dissolved away

You may see a fine sediment at the bottom of the jar around the base of the specimen; what do you think this is?

This sediment is mud from the matrix that has been released by dissolution of the calcite.

When you have finished with the vinegar, pour it down the sink and wash the jar thoroughly. ◀

The reaction of calcium carbonate with acid releases carbon into the atmosphere that has been locked up in this particular part of the geological carbon reservoir (in the 'carbonate rock' reservoir of Block 2, Section 8) for over 300 million years — the time that has elapsed since the rock formed at the bottom of some long-vanished sea.

Summarize your observations and interpretation of Specimen 3 in Table 9.1.1.

You have now looked at two sedimentary rocks, which have a fragmental texture. Before looking individually at the remaining three rocks, Specimens 4, 5 and 6, we will consider all five rock specimens together to look for any general features.

Task 5 Comparing and grouping different rock types

You have already discovered that Specimens 2 and 3 are both fragmental sedimentary rocks, so they can be grouped or classified together by their mode of formation. Now consider the remaining three specimens and look for similarities or differences that might help you to decide whether they can be grouped with the first two specimens or whether they are the result of different geological processes. Start by looking at the three basic characteristics of each specimen.

Specimen 4

- Colour:
- Grain size mm
- Texture: Does the specimen have a fragmental texture in which separate grains are cemented together, or does it have a texture of interlocking crystals which appear to have grown together?

Specimen 5

- Colour:
- Grain size/mm
- Texture: Fragmental or interlocking crystals?

Specimen 6

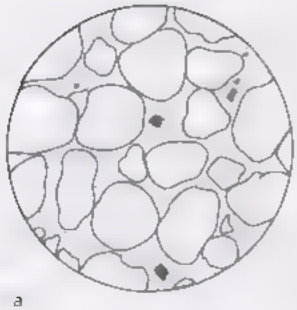
- Colour:
- Grain size mm
- Texture: Fragmental or interlocking crystals?

From your observations, do these specimens have any features that would lead you to group them together, and in a separate group from the two sedimentary rocks you have examined already? ◀

The final question above may have caused you some head-scratching. You'll probably agree that, at first glance, the differences between these rocks are more obvious than any similarities, so you may well have answered 'no'. The general appearance of each rock is different. You should be able to see that the specimens vary in colour (Specimen 6 is much paler-coloured than Specimens 4 and 5). They also vary in grain size (Specimen 5 has smaller grains than Specimens 4 and 6). However, unlike the two sedimentary rocks

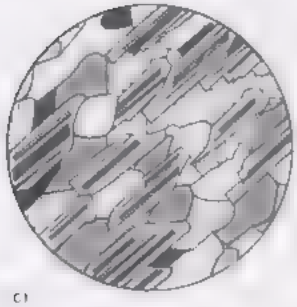
examined earlier, all of these three specimens have a texture characterized by interlocking crystals (Figure 9 1.4). This texture of interlocking grains is called a *crystalline texture*: each of the grains is a separate mineral crystal which has grown into its neighbour. Look again at the specimens with your hand lens. You should be able to see that there are no gaps at the joins, unlike in the sandstone where the neighbouring grains only partly touch each other.

This crystalline texture is the key piece of evidence that allows us to group these rocks together as being different from the two sedimentary rocks. However, in order to identify the rock types and the processes that formed them, you now need to look in more detail at each specimen in turn.



a

b



c)

Figure 9.1.4 Sketches illustrating examples of (a) fragmental, and (b) and (c) crystalline rock textures. The different minerals in each rock are distinguished by different shading. Each view represents a magnified piece of rock a few millimetres across.

Task 6 Observation and description of Specimen 4

Look carefully at Specimen 4. Look at the specimen from different angles and use your hand lens to examine it in detail. Make a note of the colour, grain size and texture that you saw in Task 5, and also any other features, such as distinctive mineral colours or shapes, and any layering or colour banding within the specimen. ◀

Look at the Comments on this activity for Task 6 before continuing

The shiny mineral flakes are best seen on the rough uncut surface of the specimen, using the hand lens. These are flat, platy crystals of the mineral mica. It is the arrangement of these platy mica crystals in layers that gives this rock its banded appearance and allows it to split along the planes between the plates of mica. You may also be able to see round grains of a reddish mineral, often with a glassy appearance. These are crystals of garnet.

The layering in this specimen is usually easiest to see on one of the smooth cut surfaces. You might be able to prise away parts of the specimen with a fingernail; these bits of the rock tend to flake off along planes of weakness which lie parallel to the layers in the rock.

Interpreting Specimen 4

This layering is produced when rocks become subjected to great pressure many kilometres down within the Earth. This causes the atoms within pre-existing minerals to become rearranged, forming themselves into new minerals. Because the crystals of these new minerals have grown together, they have an interlocking texture. The rearrangement of atoms is effectively a chemical reaction that occurs in the solid state, allowing one set of minerals to react and form a new set of minerals. Earth scientists call this process *metamorphism*, which means 'changing form'. Specimen 4 was formed by metamorphism, so it is called a **metamorphic rock**.

Metamorphism takes place where rocks are heated and subjected to high pressure. When the rocks are being compressed more strongly in one direction than another, then minerals such as mica that often form flat, platy crystals tend to grow in flat layers at right angles to the compression, rather than forming in random orientations. The layered alignment of minerals is typical of metamorphic rocks formed in this way. The reddish garnet that you may be able to see is a mineral found in many metamorphic rocks.

Specimen 4 is one particular type of metamorphic rock; some metamorphic rocks have much larger crystals and coarser banding, others have very much smaller crystals. The specific name given to metamorphic rocks with similar grain size to Specimen 4 is *schist* (pronounced 'sh-ist'). This specimen came from near Pitlochry, Scotland.

Summarize your observations and the interpretation of Specimen 4 in Table 9.1.1.

Task 7 Observation and description of Specimen 5

You saw in Task 5 that Specimen 5 also has a crystalline texture. However it looks very different from Specimen 4. Examine the specimen and write a description of it in note form. Note the texture, colour, grain size, and any distinctive features, as you did for Specimen 4.

Do you think this rock formed by the same process as Specimen 4? Explain your answer. ◀

Look at the Comments on this activity for Task 7 before continuing

Interpreting Specimen 5

Like the schist you looked at in Task 6, this rock has a crystalline texture. However, the crystals in this rock were free to grow in any direction, whereas in the metamorphic rock the crystals grew aligned in layers or bands.

Can you suggest conditions in which these crystals might have grown?

The crystals might have grown from a liquid.

The crystals in this rock grew from a molten magma (Section 8) as it cooled down. Rocks formed from the solidification of magma are called **igneous rocks**. (The word igneous is derived from the Latin word *ignis*, meaning 'fire'.) The crystals interlock at their edges where they grew into one another when the space around them was used up.

Large crystals take a long time to form. What do you think the small size of most of the crystals tells us about the speed at which the magma cooled?

The crystals are small because they didn't have much time to grow any bigger. Therefore we can conclude that the magma cooled rapidly

You may also have noticed round holes or voids in the specimen. They may be anything from less than a millimetre across to several millimetres across. These holes are caused by the presence of gas bubbles, at the time the magma was cooling, gas was escaping but some of it got trapped in the solidifying magma.

Where on the Earth would you expect to find gas escaping from magma?

The magma that erupts from volcanoes emits gases, so you might expect that this rock originally came from a volcano.

So the presence of gas bubbles, and the small size of the crystals indicating rapid cooling, tell us that this particular magma was erupted by a volcano onto the Earth's surface where it cooled rapidly to become an igneous rock. Volcanic rocks such as this are called *extrusive igneous rocks*, because they have been 'extruded' onto the Earth's surface. This particular specimen was collected from an ancient lava flow from the Auvergne region of France, an area which has been volcanically active over the last 70 000 years.

But why does this rapidly-cooled lava have some larger crystals within it?

What does the size of these crystals suggest about their rate of cooling?

The larger crystals must have had more time to grow when the magma was not cooling so rapidly

In fact, a volcanic rock such as Specimen 5 would have started to cool in a magma chamber underground, allowing a few large crystals to grow. Then, when the magma was erupted, gas bubbles fizzed out of the magma, as they do when a bottle of fizzy drink is opened. As the lava cooled quickly at the surface, solidification became complete with the growth of tiny crystals which trapped some of the gas bubbles in the volcanic rock.

Specimen 5 is an example of the volcanic rock *basalt*. Basalt is the most common igneous rock on the Earth's surface, largely because the ocean floor is made of basalt. It's also intriguing that basalt makes up most of the surface of the other terrestrial planets and the Moon.

Although each specimen is slightly different, it's likely that your Specimen 5 will have some brown or orange staining on some surfaces. These stains formed after the magma cooled and are caused by chemical reactions between water and the rock long after the rock solidified, so they are unrelated to the origin of the rock and we can ignore them here.

Summarize your observations and interpretation of Specimen 5 in Table 9.1.1.

Task 8 Observation and description of Specimen 6

The final specimen to examine is another crystalline rock. Use the hand lens to look at the flat face of this specimen, which shows the mosaic of interlocking crystals more

clearly. The rock is a three-dimensional jigsaw. Each grain joins up and interlocks with every other grain around it so there are absolutely no spaces between

There are three different types of crystal in this specimen. Note (very briefly) the colour of each type, and estimate their size (but note that several crystals of the same mineral may be joined together, giving the impression of a larger size).

1

2

3

Check your descriptions with the Comments on this activity for Task 8 before continuing

Interpreting Specimen 6

Do you think that this crystalline rock is metamorphic or igneous?

We've noted that only in the schist specimen are the crystals arranged in approximately parallel layers, and that is a feature of metamorphic rocks. There is no layering in the igneous rock, Specimen 5. In Specimen 6, the crystals make up an interlocking mosaic with no obvious layering present, so it is unlikely to be metamorphic and more likely to be igneous.

This is another igneous rock, this time made of crystals that are large enough to be seen without the hand lens

What does the size of these crystals suggest about their rate of cooling?

The large crystals must have taken a long time to grow, so the magma must have cooled very slowly (much more slowly than the magma that formed the basalt, Specimen 5)

When this rock solidified from molten magma, the crystals were able to grow to relatively large sizes before the whole rock was completely solid. The longer the cooling time, the larger will be the crystals (all else being equal)

We said that Specimen 5 cooled rapidly when magma was erupted onto the surface. In what environment do you think slow cooling of magma might occur to give the large crystals seen in this specimen?

Slow cooling would occur when magma cooled underground; for instance in a magma chamber or where magma has been intruded into existing rocks.

This rock was formed when molten magma was intruded into existing rocks and cooled slowly. It is therefore called an *intrusive igneous rock*. The name of this particular type of intrusive igneous rock is *granite*. Granite is defined as an intrusive igneous rock containing the minerals *quartz* (the grey glassy crystals) and *feldspar* (the white, sometimes rectangular crystals), with smaller amounts of *mica* (the black flakes). These three minerals account for virtually all of the rock, and they are the three minerals you should have been able to distinguish by colour in Task 8.

Specimen 6 comes from Dartmoor. When you are holding Specimen 6, you are holding the solidified product of a magma that cooled from maybe 800 °C at a depth of several kilometres below the Earth's surface about 280 Ma ago, and since then has been uplifted to the surface

Summarize your observations and interpretation of Specimen 6 in Table 9.1.1.

Review

To conclude this activity, you can reflect that we've been able to use a rock's texture, as observed in a hand specimen, to tell us the way in which the rock formed. This revealed that there are three main ways in which rocks form. In the first case, the sandstone and limestone are *sedimentary* rocks, with fragmental textures, that form by the

accumulation of sedimentary grains. The specimen of schist is a *metamorphic* rock, and has an interlocking, intergrown, crystalline texture. Schist is formed by recrystallization under pressure, this causes platy mica flakes to grow in corrugated layers, which allow the rock to break apart along these planes of weakness. *Igneous* rocks also have an interlocking, intergrown, crystalline texture, but the crystals have grown in random orientations. *Intrusive* igneous rocks such as granite form by the slow cooling of magma at depth, resulting in large grain sizes. *Extrusive* igneous rocks such as basalt are formed when volcanic eruptions bring magma to the Earth's surface where it cools quickly. They have smaller grain sizes, and they sometimes contain holes once occupied by escaping volcanic gases.

Your completed Table 9.1.1 provides a record of your observations and a summary of the main features of the different rock types. You should compare it with Table 9.1.2 in the Comments on this activity.

Activity 9.2 Summarizing the distinguishing features of different rock types

The rock specimens examined in Activity 9.1, and those described in Section 9, indicate that sedimentary, metamorphic, extrusive igneous and intrusive igneous rocks have their own distinguishing features. Summarize these features by completing Table 9.2.1.

Table 9.2.1 Summary of rock features

	Sedimentary	Metamorphic	Extrusive igneous	Intrusive igneous
texture (fragmental or crystalline)				
for rocks with crystalline texture, do the crystals have random orientations or are they arranged in layers?				
can fossils be present?				
for igneous rocks, describe the grain size and how it relates to cooling rate				

Activity 10.1 Summarizing different lines of evidence about the interior of the Earth

Note that you are asked for only three sentences here. Try to restrict yourself to just one sentence per line of evidence (i.e. one sentence on the conclusion reached from drilling, one sentence on the conclusion reached from density measurements and one sentence on the conclusion reached from the occurrence of peridotite at the Earth's surface). This is a useful exercise in picking out the important points from a section of text.

Activity 10.2 Investigating seismic waves

(*The estimated time for this activity is 25 minutes.*)

In this DVD-multimedia activity you will investigate the different types of seismic wave that travel through the Earth. 'Journey to the centre of the Earth' has an introduction and three main sections. For this activity you should study the introduction and the first of the main sections, 'Seismic waves'.

'Journey to the centre of the Earth' is on the Block 3 DVD. To start this activity, you need to open the DVD Multimedia Guide on your computer, and click on the 'Journey to the centre of the Earth' button in the Block 3 folder. You should start this activity now.

Activity 10.3 Travel time graphs

(*The estimated time for this activity is 30 minutes.*)

In this activity you will use earthquake travel time graphs to measure the P-wave speed in the upper layer of the Earth, and to determine how deep this layer extends. You should work through 'Travel time graphs', the second main section of 'Journey to the centre of the Earth'. The section is divided into a number of stages, in which you will interpret travel time graphs, model the Earth's crust, and investigate a deeper layer of the Earth

'Journey to the centre of the Earth' is on the Block 3 DVD To start this activity, you need to open the DVD Multimedia Guide 3 on your computer, and click on the 'Journey to the centre of the Earth' button in the Block 3 folder. You should start this activity now.

Activity 10.4 Summarizing information about the crust in a table

Complete Table 10.4.1 so that it provides a summary of crustal characteristics. You will have to use information from Sections 6.3 and 9.5, as well as from this section. Remember to include the units for any values that you use. Recording key information in a table such as this can be a useful revision tool

Table 10.4.1 Characteristics of oceanic crust and continental crust

	Oceanic crust	Continental crust
thickness	7 km	20- 60 km average km
mean P-wave speed	7 km s^{-1}	6 k
density	about 3.0 x 10^3 kg m^{-3}	2.8 x 0^3 kg m
rock types	Basalt	Sedimentary

Activity 10.5 Down to the centre

(*The estimated time for this activity is 20 minutes.*)

In this activity you will use travel time graphs to model the rock type of the mantle, and to investigate down to the centre of the Earth. You should work with the last main section of 'Journey to the centre of the Earth', which is in two parts: 'Modelling the mantle' and 'Down to the centre.'

'Modelling the mantle' investigates travel time graphs at greater distances than the previous section (Activity 10.3), corresponding to greater depths in the Earth. 'Down to the centre' investigates what happens below the mantle, at still greater distances on travel time graphs

'Journey to the centre of the Earth' is on DVD 1. You should start this activity now.

Activity 10.6 Reviewing your study so far

(*You should spend about 20 minutes on this activity, including watching the DVD-video.*)

(a) Planning and managing your study

Turn back to the study plan you drew up in Activity 1.1. Have you been tracking your progress against this plan as you work through the block? Have you achieved what you planned?

You may be ahead of schedule at this point, which would be good, since it leaves time for you to cope with anything unexpected that crops up (or even to take a holiday!) On the other hand, you may not have achieved what you intended, perhaps because there have been unexpected demands on your time. If so, you should make some contingency

plans. Think about how you might catch up. Can you plan some extra study time, or alternatively find ways of streamlining what you are doing so that you make faster progress through the block? Is there something specific which is holding you back, and if so how can you sort it out?

The five-minute DVD-video activity 'Keeping up' shows a number of OU students discussing their strategies for making up lost time. If you are behind, it should reassure you that you are not alone, and may give you some useful hints about catching up!

'Keeping up' is on DVD 1 (DVD-video sequence 314–331). Now would be an appropriate time to view this

If you are concerned about how your study of the block is progressing, or would like advice on catching up, do talk it over with your tutor. It is best to take action early, before the molehill becomes a mountain.

(b) Making your learning of the science content as effective as possible

This halfway point in the block is a suitable time to reflect on how effective you feel your learning of the science in the block has been so far. Look back at your notes on part (b) of Activity 1.1, where we suggested that you note down the study strategies that you planned to use in this block. Annotate your list to indicate which of these strategies you have used successfully, and where, and which you have tried out but found unhelpful, and why it is you think they didn't help. Then make a note of any changes that you will make to your strategies for the second half of the block.

Learning from DVD-multimedia. Quite a lot of Section 10 is based on DVD-multimedia activities. How easy did you find it to learn effectively from these activities? Did you manage to complete them in the suggested time? Watching pictures or listening to an audio track from a DVD can seem like an easy way of absorbing information. But are you really learning? When the pictures and words have gone, how well can you recreate or explain the images you saw? To help you learn, you need to make notes to 'fix' the knowledge and understanding in your mind. Spend a few minutes thinking about how you did this for the 'Journey to the centre of the Earth' activities, and how effective it was.

(c) Becoming aware of the different skills that you are developing

Have you been able to identify the skills related to diagrams and tables that you have been developing as you have worked through the questions and activities? Did it help to refer to the appropriate objectives at the start of the block? Are there any aspects of working with diagrams and tables that you are uncertain about, or with which you feel you need further practice?

Activity 11.1 Fossils and the continental jigsaw

Examine the map in Figure 11.2 of the book, and note the locations of a fossil which we have not yet discussed: *Glossopteris*. This was a fern which lived at around the same time as *Mesosaurus* — about 260 Ma ago. Complete Table 11.1.1 by noting on which continents fossils of *Glossopteris*, *Edaphosaurus* and *Mesosaurus* occur. Then consider whether this new evidence supports the continental drift hypothesis. In order to help you do this you should consider the following questions:

(a) Does the evidence yielded by the *Glossopteris* fossils support the hypothesis?

(b) What does the new evidence imply about the position of India over time?

(c) Based on the fossil evidence, which continents and landmasses do you think were joined between 280 and 260 Ma ago?

Table 11.1.1 Locations of fossils across the world at 280 Ma and 260 Ma ago

Age/Ma	Fossils	Locations
260	*Glossopteris*	
260	*Mesosaurus*	
280	*Edaphosaurus*	

Activity 11.2 Fossil compasses in Africa and India

(*You should spend about 15 minutes on this activity*)

In this activity you will use information from Figure 11.5 in the book to test the continental drift hypothesis. This continues the theme of interpreting diagrams and explaining their meaning in words

Figure 11.5 shows the palaeolatitudes of eastern Africa and southern India over the last 300 Ma. Study the graph carefully and answer the following questions:

(a) Did the positions of the two continents change during the last 300 Ma?

(b) If their positions did change, did both continents follow the same route for part of the time?

(c) Did the two landmasses diverge from each other at any time?

(d) Now write about 200 words describing what happened to India and Africa in the last 300 Ma. You may find it useful to look back to the advice in Activity 7.2a on describing a diagram in words. As with any piece of writing, it is important to express your answer in a logical way. In this case it is probably best to describe what happened as time progressed. You have already identified key points in your answers to parts (a)–(c). In writing a 200-word account, you will probably want to extract some more detailed information from the graph, but remember that it is the key points that are important.

(e) In conclusion, does Figure 11.5 support the hypothesis of continental drift?

multimedia

Activity 12.1 Exploring the Mid-Atlantic Ridge

(*You should spend no more than 45 minutes on this activity*)

This activity consists of two tasks, based around the DVD-multimedia activity 'Exploring the Mid-Atlantic Ridge'. Before starting this activity, you might find it helpful to look back briefly at the notes and comments for Activity 10.6b, in which we asked you to think about the time you were spending on the DVD activities and about how you were making notes for these activities.

The DVD contains a large amount of information in the form of maps, models of the ocean floor, video clips, photographs and text describing features at the Mid-Atlantic Ridge and the East Pacific Rise. You can explore this resource as much as you wish, but this activity requires you to concentrate your time on a virtual trip aboard a submersible to the Mid-Atlantic Ridge, 3 km below sea-level. In this part of the activity you will be able to move around a highly-stylized representation of the valley running along the centre of the Mid-Atlantic Ridge. The DVD gives you the ability to identify various features and to consult a 'library' to see video clips, photos and explanations of the features. The most important library entries are highlighted, so you should be sure to visit those. As you explore this environment you should look for information that will allow you to complete the following two tasks.

Task 1

Locate and visit each of the following areas on the Mid-Atlantic Dive portion of the DVD and write two or three sentences describing each feature and the process that produces it:

- active black smoker
- fissure
- scarp face
- hydrothermal mound (there are two examples of this, showing similar features and both inhabited by a range of organisms)
- derelict hydrothermal area
- lava flow
- sediment.

The order in which you visit these areas is not important. Your notes on the processes at work at the centre of the mid-ocean ridge are needed for Task 2.

Task 2

Apart from the fine sediment on the ocean floor, all of the features identified in Task 1 are caused, in various ways, by sea-floor spreading — the pulling apart of ocean crust at a mid-ocean ridge coupled with intrusion and extrusion of magma at the ridge. (There is an animation of the sea-floor spreading process on the DVD.) But what evidence is there to suggest that sea-floor spreading occurs? Decide whether each feature noted in Task 1 gives evidence for (a) pulling apart of the ocean crust, or (b) the presence of hot material below the mid-ocean ridge, and briefly summarize this evidence in the appropriate column of Table 12.1.1.

'Exploring the Mid-Atlantic Ridge' is on DVD 1. You should start this activity now

Table 12.1.1 Evidence for sea-floor spreading processes.

Name of feature	Evidence that the crust is being pulled apart on either side of the mid-ocean ridge	Evidence that hot material underlies the mid-ocean ridge

Activity 12.2 Sea-floor spreading rates on the Southeast Indian Ridge

(*You should spend no more than about 45 minutes on this activity.*)

In this DVD-multimedia activity you will use the geomagnetic polarity time-scale and marine magnetic anomalies from the Southeast Indian Ridge to measure the sea-floor spreading rates at points along the ridge. The activity develops data handling and graph plotting skills within the context of measuring sea-floor spreading rates, providing lots of practice and feedback on plotting and using graphs and calculating their gradients.

When you have finished the activity, you should complete the piece of text below to summarize your results. Glance through this before starting the activity, so that you are aware of the information that you will need to complete the passage.

In this study, marine magnetic anomalies from ..... (*number*) traverses across the Southeast Indian Ridge were used to find the average rate of sea-floor spreading during the last ..... (*number*) Ma.

The results show variation from a minimum spreading rate of ..... (*number and unit*) to a maximum rate of ..... (*number and unit*).

Moving from northwest to southeast along the Ridge, the sea-floor spreading rate increases/decreases*, reaching a maximum/minimum* of about ..... (*number and unit*) at a point

..... (*describe geographical location in words*)

near .. .. (*latitude*) , ... (*longitude*) before increasing/decreasing*.

*delete the inappropriate word

'Rates of sea-floor spreading' is on DVD 1. You should start this activity now

Activity 13.1 Completing a table of plate boundary features

Complete Table 13.1.1, using information from Section 13.2 and from earlier sections in the block. This is another example of a summary table, which will help you to identify, remember and revise the key features of different types of plate boundary.

Table 13.1.1 The characteristics of each type of plate boundary.

	Divergent	Convergent	Transform fault
direction of motion of plates with respect to plate boundary			
depth of earthquake foci (shallow, intermediate, or deep)			
destruction or creation of lithosphere, or neither			
physical features associated with boundary			

Activity 13.2 Using a physical model to help understand plate motion

This is an activity to help you visualize the situation shown in Figure 13.5 in the book. Draw an enlarged version of Figure 13.5a on a sheet of paper, and cut out plate A along the plate boundaries. Now place plate A back inside plate B, and move A in the direction shown by the arrow on A, towards the left. Observe what happens at each of the edges of rectangle (plate) A. Which type of plate boundary is each edge of A analogous to?

Activity 13.3 Plate tectonics on a sphere

(*The estimated time for this activity is 1 hour and 15 minutes*.)

This DVD activity is an investigation of how plates move relative to each other on a spherical Earth. After a short introduction, it has five sections. 'Spreading rates' investigates how and why the rate of sea-floor spreading varies with distance along a divergent plate boundary (as studied in Activity 12.2). 'Poles of rotation' illustrates how the relative motion of two plates on the Earth is a rotation about an axis that passes through the centre of the Earth. The remaining three sections are tasks that involve determining poles of rotation and predicting plate motion, based on the plate tectonics investigated in the first two sections.

'Plate tectonics on a sphere' is on DVD 1. You should start this activity now.

Activity 14.1 Compare and contrast different types of convergent plate boundary

(*You should spend no more than about 20 minutes on this activity*.)

You have seen that there are three types of convergent plate boundary, depending on the types of lithosphere at the boundary. In this activity we want you to write a brief account to *compare and contrast* these three types of convergent plate boundary.

Note the 'compare and contrast'. So far, when producing a written account you have been asked to 'describe' or 'explain'. This is different! As explained in *SGSG*, Chapter 9, it is very important to do what you've been asked to do in a question (and not doing so is a frequent cause of substantial loss of marks in TMAs). 'Describe', 'explain', 'compare', 'contrast' are sometimes known as 'process words', and others include 'criticize', 'define', 'illustrate', 'discuss'. They all have (sometimes subtly) different meanings. Possible definitions of compare and contrast are:

> *compare* — look for similarities (and perhaps reach a conclusion about which is preferable)
>
> *contrast* — set in opposition in order to bring out differences.

So on this occasion you need to look for *similarities* and *differences* between the three types of convergent boundary. This is not quite the same as what you did in Activity 10.4 and Activity 13.1. There you simply put information about different features into a table, but here you need to point out explicitly the ways in which the plate boundaries are similar to each other and the ways in which they are different. However, you might find it helpful to start by producing a table with three rows, one for each type of convergent boundary, and with different features noted in each column. You can then use this information as you write up an account with a logical flow, probably concentrating on one feature (e.g. the presence or absence of earthquakes) at a time. You should discuss surface features, earthquakes and volcanic activity, and should aim for an account that is about 200 words long.

Activity 14.2 Using plate tectonics to explain the active Earth

(*You should spend no more than about 25 minutes on this activity*.)

Western North America and the adjoining Pacific Ocean floor is a region that is subject to volcanic and earthquake activity. This can be explained by plate tectonics, and this activity allows you to discover how the simple system of plate boundaries shown in Figure 14.12b of the book can account for the observations and features shown in Figure 14.12c. You are asked to collate your work in Table 14.2.1 (*overleaf*) by completing each of the unfilled cells. We suggest that you complete the table systematically by filling the second column first and then working column by column across the table from left to right. Some cells in the table have already been completed to give an indication of the style of answer expected.

Table 14.2.1 Features of plate tectonics near the west coast of North America.

Boundary on Figure 14.12b	Name of plate boundary on Figure 14.12c	Relative plate motion	Associated phenomena
AB		subduction of the Pacific Plate beneath the North American Plate	
BC			zone of shallow-focus earthquakes
CD			
CE	Cascadia Subduction Zone		
DE			zone of shallow-focus earthquakes
EF		Pacific Plate slides past North American Plate	zone of shallow-focus earthquakes
FG	part of a sea-floor spreading system connected by transform faults to the East Pacific Rise		bacterial mats, clams and tube-worms found associated with hydrothermal vents in the Gulf of California

(a) Compare the sketch of plate boundaries in Figure 14.12b with the distribution of plate boundaries, seismic zones and volcanoes of western North America in Figure 14.12c. Each plate boundary in Figure 14.12b can be identified by the pair of letters at either end of it. Using this notation, match the plate boundaries in Figure 14.12b with the features named in Figure 14.12c, and enter the names of the features in the second column of Table 14.2.1.

(b) For each plate boundary, state the names of the two plates involved and describe their relative movement, writing your answer in the third column of Table 14.2.1.

(c) Each of the following phenomena can be related to one of the plate boundaries shown in Figure 14.12c. Some of these phenomena you will already have met in this course; others may be new to you. Most are landmarks in the history of the scientific study of the Earth. Decide which plate boundary is associated with each of the phenomena and make a note of the phenomena in the appropriate rows in the fourth column of Table 14.2.1.

(i) The 1980 eruption of Mount Saint Helens volcano, the first large volcanic eruption to be studied so intensively, using modern technological instrumentation, that the information gained provided a great leap forward in understanding how volcanoes work.

(ii) The Juan de Fuca Ridge was included in the first map of marine magnetic anomaly patterns to be obtained across a mid-ocean ridge (1961). The information on that map led the way to confirming sea-floor spreading.

(iii) The 1964 Alaskan earthquake, a magnitude 8.4 event with a focus near the Aleutian Trench in a Wadati–Benioff zone 30 km below the Pacific Ocean.

(iv) The 1912 eruption of Katmai volcano, the largest explosive eruption of the 20th century (at the time of writing).

(v) Large earthquakes in San Francisco and Los Angeles; location of experiments to predict and trigger earthquakes.

multimedia

Activity 16.1 Plate motion in the past and future

(*The estimated time for this activity is 1 hour.*)

This DVD activity is an investigation into the positions of plates and continents in the past 400 Ma and predictions for the future 100 Ma. It starts with an introduction to the principles of plate reconstruction. This presents the different types of data that can be used to reconstruct the positions of plates in the past, with their limitations. You will then use a number of different types of reconstruction to investigate the movement of plates and continents over the last 400 Ma.

In the third section of the activity you can investigate the positions of the UK, India, Australia, or Gondwana over the last 400 Ma.

In the fourth and fifth sections you will investigate how present-day data can be used to predict future plate movements, and then investigate the possible future of plates, continents and oceans up to 100 Ma from now.

'Plate motion in the past and future' is on DVD 1. You should start this activity now.

Activity 17.1 Using a diagram of the rock cycle

Use the information about the rock cycle summarized in Figure 17.3 of the book and your knowledge of rocks from earlier sections to do the following:

(a) Outline how the minerals in sedimentary rocks exposed at the Earth's surface can be converted into metamorphic rocks.

(b) Outline two different processes by which the materials in an intrusive igneous rock could be converted into a metamorphic rock.

(c) How might an atom which was originally in the mantle end up in a sedimentary rock? Outline the various ways for the atom to make this journey.

Activity 18.1 Reviewing your study of Block 3: learning from different resources

(You should spend about 30 minutes on this activity.)

There are three parts to this activity. In the first, you should reflect on your management of study time. In the second you should update your advice to yourself on how to learn effectively from the DVD-video and DVD-multimedia activities. In the third you should reflect on the use of tables and diagrams in this block, and try out a method of helping you to develop skills throughout the course.

(a) Managing study time

Look back at the study plan you made in Activity 1.1, and at your review of progress in Activity 10.6. How well did you follow your plan? Did anything unexpected crop up, and did you successfully modify your study plan to cope with this? Did you make any changes as a result of the review in Activity 10.6? If so, how well did they work out?

Make a note of any advice you can give yourself *now* about managing your study in the next block and in the remainder of the course.

(b) Effective learning from DVD

What have you discovered while studying this block about the way you learn best from DVD-video and DVD-multimedia activities? Spend a few minutes thinking about whether you are getting the most out of these activities.

For DVD-video activities, think back to the way you studied the 'Volcanoes' sequence (Activity 8.1). How did you go about this? What sort of notes did you take? Were they adequate to complete the tasks? Will you approach the next DVD-video in the same way, or will you try a different approach?

For DVD-multimedia activities, you may well have tried a variety of different approaches, since there are seven multimedia activities in this block. Have you now sorted out a good way of making notes about what you have learned in these activities, either on paper or using the computer? Were you able to explore the Mid-Atlantic Ridge and find the important information in the suggested time? Do you now feel fairly comfortable about learning from these multimedia activities?

Make a note of any ways of working with the DVD-multimedia activities that have been particularly successful, and also of any that have been unsuccessful, and if possible try to think why they have been successful or unsuccessful. It would be worth making a note of any advice that you want to give yourself about how you should approach the activities in the next block — as a reminder to yourself when you are about to study them.

(c) Skills development

Studying this block has given you a lot of practice in working with tables and diagrams of many types. *Tables* are a useful way of summarizing information, classifying things, and showing similarities and differences between things — and sometimes a table does all three of these things. Producing a table for yourself also helps you to consolidate your understanding of a topic. Spend a couple of minutes looking back through the tables in the Study File, and ask yourself what the main purpose of each table was.

There are a wide variety of different types of *diagrams* in this block — maps, photographs, schematic diagrams of parts of the Earth, graphs, and so on. If there are particular types of diagram that you find it difficult to 'read', then you may wish to look back at some examples of these now that you have completed the block. You may find that your experience of working with diagrams allows you to understand them more easily now.

A useful method of developing a skill — such as the skill of reading diagrams — is to reflect on how you actually use that skill, and we have encouraged you to do this in the activities at the end of Blocks 1 and 2. An effective way of doing this is to choose a *specific* task where you use a particular skill, to carry out the task, and then to note down how you actually did it. Having completed that stage, you note down a *general* description of the process that you followed. This general description can then be used as a framework for tackling the next task of the same kind.

The following example (Table 18.1.1) shows how one student used this method to reflect on skills associated with using diagrams, after she had done Activity 11.1. The second column in the table demonstrates the outcome of the process of reflection in this case: it's a generalized description of the process that the student went through.

Table 18.1.1 A student's review of her use of a diagram in Activity 11.1.

What specific task did I do?	What general kind of thing did I do?
I looked for evidence to support the continental drift hypothesis; examined Figure 11.2 to see where different types of fossils had been found.	Looked for specific information from a diagram to confirm hypothesis.
I worked systematically with the map, looking at the location of each fossil in turn.	Worked systematically with the diagram, looking at each item in turn.
I noted that the two places where *Mesosaurus* were found and the two places where *Edaphosaurus* were found could be juxtaposed by sliding America and Europe together, so that the coastlines fitted. Also the five places where *Glossopteris* fossils were found could be joined by sliding Antarctica, Australia and India together into contact with South America and Africa.	Recorded observations; suggested an explanation.
This supported the hypothesis that the continents were joined together at one time and have since drifted apart – i.e. continental drift.	Used observations as evidence to support hypothesis. (In other circumstances, the evidence might have led to modifying or rejecting a hypothesis.)

Now use this method to analyse some of the skills you have been developing in working with diagrams. Pick a couple of diagrams from the block, imagine that you are meeting them for the first time, and note down how you go about 'reading' them. Then turn your notes into general advice on how to go about reading a diagram. When you have assembled your general advice, read it through, and see if you can think of any improvements.

You should complete your study of Block 3 by trying the questions on the Block 3 DVD

Acknowledgements

Grateful acknowledgement is made to the following source for permission to reproduce material in this study file:

Figure 7.1.1: Kessler, D. (1995) 'An awesome shudder like the end of the world', *The Guardian*, 18 January 1995 © Guardian Newspapers Ltd.

Comments on activities

Activity 1.1

(a) Your study plan will be tailored to your own circumstances and study preferences, so there are no specific comments on this activity. However, remember to monitor your progress against the plan that you have drawn up. You may find after working through a few sections that you are not keeping very closely to your plan. If that is the case, you will need to adopt one of two strategies: either restrict the amount of time you spend on sections of the block or on the DVD-multimedia activities, or amend your study plan to allow more time for study each week.

(b) By the end of Block 2, your list of learning strategies might have included some or all of the following.

- Scan the block, or sections of it, before studying it properly.
- Use the end of section summaries for orientation and to see what is important.
- Refer to the TMA questions early on to focus study.
- Make notes while studying, for DVD activities as well as book.
- Highlight only really important ideas.
- Try to understand a concept by thinking about lots of examples of where it applies (and where it doesn't apply).
- Use an analogy to picture a difficult concept.
- Relate new ideas to previous knowledge.
- Make a summary at the end of a section.
- Check the objectives to make sure important points are understood.

Different people have different ways of working — hence the variety in the list above. You may well have listed other learning strategies, some of which you are planning to use for the first time with this block. It is important at this early stage of the course to try out a variety of different strategies to see what works best for you, so the more ideas you pick up from other students or your tutor the better!

Since you may not have used DVD activities as learning resources before, it may take you a while to establish the best ways of learning from them. DVD-multimedia activities in particular, because of their interactivity and flexibility, require a fairly disciplined approach, as we pointed out in the notes that accompanied the first DVD-multimedia activity (Activity 8.5 in Block 2) and you may like to refer back to these notes now.

(c) Awareness of what skills you are developing and using will allow you to apply them more widely, not only in other areas of *Discovering Science*, but also outside the course. In the context of diagrams and tables, the skills you develop in this block may well be of value when reading newspapers and magazines, or when you are involved in various projects around the home or garden (not to mention the world of work).

Activity 3.1

(a) (i) To determine the scale factor we use the same procedure as in the example of the architectural model.

1.00×10^{-4} m in the model corresponds to 6.37×10^{6} m in the real Galaxy, so:

$\frac{1.00 \times 10^{-4}\,\text{m}}{1.00 \times 10^{-4}} = 1\,\text{m}$ in the model corresponds to $\frac{6.37 \times 10^{6}\,\text{m}}{1.00 \times 10^{-4}} = 6.37 \times 10^{10}\,\text{m}$ in the real Galaxy.

So the scale of the model is $1 : 6.37 \times 10^{10}$.

(ii) To find the values for the other model distances we simply divide the actual distance by the scale factor. So for the radius of the Sun, the scale model value is:

$$\frac{6.96 \times 10^{8}\,\text{m}}{6.37 \times 10^{10}} = 1.09 \times 10^{-2}\,\text{m} = 10.9\,\text{mm}.$$

The answer is given to three significant figures, the same as in the data. In the scale model, the Sun would thus have a radius of 10.9 mm. The other two values required to complete Table 3.1.1 were calculated in the same way, and are shown in Table 3.1.3.

Note that the scale model values have been expressed to an appropriate number of significant figures; non-significant zeroes have been italicized in the last column.

The scale model values might give you a better impression of how far off the nearest star is compared with the Sun. In the model, the Sun is a couple of metres away from the Earth, but the nearest star is 626 000 000 mm (626 km) away, which is roughly the distance between London and Aberdeen.

Table 3.1.3 Completed version of Table 3.1.1, A scale model of the Galaxy, in which the Earth's radius is 0.100 mm.

Size or distance	Actual value m	Scale model value m	Scale model value, mm
radius of the Earth	6.37×10^{6}	1.00×10^{-4}	0.100
radius of the Sun	6.96×10^{8}	1.09×10^{-2}	10.9
average distance of the Earth from the Sun	1.50×10^{11}	2.35	2350
distance from the Sun to the nearest star	3.99×10^{16}	6.26×10^{5}	626 000 000

Table 3.1.4 Completed version of Table 3.1.2. A scale model of the Galaxy in which the distance from the Sun to the nearest star is 0.100 mm.

Size or distance	Actual value/m	Scale model value/m	Scale model value/mm
distance from the Sun to the nearest star	3.99×10^{16}	1.00×10^{-4}	0.100
diameter of the globular cluster M13	1×10^{18}	3×10^{-3}	3
thickness of the disc of the Galaxy	2×10^{19}	5×10^{-2}	50
diameter of the disc of the Galaxy	1.2×10^{21}	3.0	3 000

(b) In the second scale model the scale is $1 : (3.99 \times 10^{16}/1.00 \times 10^{-4})$, or $1 : 3.99 \times 10^{20}$. So each of the values in the second column must be divided by 3.99×10^{20} to obtain the values shown in the third column of Table 3.1.4.

Activity 3.2

This sequence started with a simple model that focused on how, in general terms, the stars in the disc of a spiral galaxy rotate around the galactic centre. The spiral arms were then added, to make the model more like a real galaxy. This is a common feature of scientific modelling — start with something simple that represents one of the essential phenomena, then add features to include other phenomena. We could have gone further with the spiral galaxy, and, for example, distinguished between stars and interstellar matter in the disc.

In Block 2 you met another model that was elaborated in stages in this sort of way — the leaky tank as a model of energy exchanges between the Sun, the Earth's atmosphere, and the Earth's surface.

Activity 5.1

Here is an answer to the first part of the activity:

> The giant planets have cores of icy and rocky materials, with an outer layer of hydrogen and helium. The theory for the origin of the Solar System is that it formed from a rotating disc of gas composed mainly of hydrogen and helium, plus a small proportion of dust. The disc was cooler farther from the Sun, so the outer part of the disc also contained icy materials. The ice and rock gathered together to give four icy-rocky bodies, which were more massive than the inner planets because of the presence of the ice. Because these objects were massive, gas from the rotating disc was also gravitationally captured, leading to a massive outer layer of hydrogen and helium in the outer giant planets only. (*125 words*)

Note that this answer includes information from Sections 5.2 and 5.4, and this has been reordered and rewritten to give a logical answer to the question asked. As you probably found in Blocks 1 and 2, assembling the information to answer a question of this type and thinking about the construction of your answer can help you to understand and remember the material.

The second part of the answer is different, since here you were asked to speculate. What follows is an answer given by a student with no previous knowledge of the subject matter:

> The subgiants Uranus and Neptune have icy-rocky cores which are larger or about the same size as the cores of Jupiter and Saturn, but their outer layers of hydrogen and helium are considerably smaller. The subgiants are farther away from the Sun than Jupiter and Saturn. The clue given in the notes implies that at this position in the Solar System, well distant from the Sun, the icy-rocky cores would aggregate more slowly than for Jupiter and Saturn. Thus the subgiants would gain mass more slowly and so would not attract hydrogen and helium in the early stages of their formation. The subgiants have probably collected rock and ice for longer than Jupiter and Saturn, but Jupiter and Saturn were large at an earlier stage and so gravitationally captured most of the hydrogen and helium from the disc before the remaining part of the disc was driven out into interstellar space. (*153 words*)

The answer is not completely correct (*an alternative answer that is more accurate is given below*), but the student who wrote it was delighted to discover how close to the truth she was. In speculating, you are beginning to *discover science* for yourself. It does not matter greatly at this stage whether your speculation agrees closely with current theory. What is important is that you are *using* the course material in order to come up with the explanation that you did. This should help you to understand the material and it is also encouraging you to think for yourself as a scientist.

The complete reason for the existence of the subgiants, according to current theory, is as follows:

> The subgiants Uranus and Neptune have icy-rocky cores which are larger or about the same size as the cores of Jupiter and Saturn, but their outer layers of hydrogen and helium are considerably smaller, as shown in Figure 5.2. The subgiants are farther away from the Sun than Jupiter and Saturn. The theory mentioned in the notes implies that at this position in the Solar System, well distant from the Sun, the icy-rocky cores would aggregate more slowly than for Jupiter and Saturn. Thus the cores of the subgiants appeared later, closer to the time when the disc of gas was driven into interstellar space by radiation from the Sun. Therefore the subgiants had less time to capture gas than Jupiter and Saturn, so they are smaller than the giant planets, which are closer to the Sun (*140 words*)

Note that (as stated in the caption to Figure 5.2) the boundaries between the icy-rocky cores and hydrogen-helium envelopes are probably more fuzzy than those shown. This does not, however, alter the essence of the above discussion.

Activity 6.1

Here is a sample list, though your list is likely to include many different items.

1. Jumping flea (biosphere)
2. Creeping ice cap or glacier (solid, hydrosphere)
3. Growing tree (biosphere, atmosphere, hydrosphere)
4. Sprinting athlete (biosphere)
5. Hurricane force gale (atmosphere)
6. Ground shaken by earthquake (solid)
7. Sand grains blown by the wind (solid, atmosphere)

8 Volcanic eruption (liquid, gas and solid, atmosphere)

9 Evaporating puddle (hydrosphere, atmosphere)

10 Flowing river (hydrosphere)

11 Clouds moving (atmosphere)

The examples here cover a wide range of size, from a jumping flea (a solid part of the biosphere and a player in the carbon cycle) to an ice cap (a solid part of the hydrosphere and part of the water cycle). A wide range in speeds is also covered, from a creeping ice cap or growing tree to a sprinting athlete (another carbon cycle participant) to a hurricane force gale (the atmosphere moves). You may have found it hard to think of things that were not involved in the water or carbon cycles, but two possible examples are the ground shaking in an earthquake (part of the solid Earth) and sand grains being blown by the wind or eroded from a beach by the action of waves. You might also have thought of volcanic eruptions, which move solid and liquid rock, and gas, from the Earth's interior to the surface and the atmosphere

Activity 6.2

A completed sketch map is shown in Figure 6.2.3.

Activity 6.3

The main features of the sketch map of the Earth's surface given in Activity 6.2 (see Figure 6.2.3) can be summarized as follows.

The major features of the Earth's solid surface are the mid-ocean ridges and ocean trenches below sea-level, and mountain belts and island arcs above sea-level. Mid-ocean ridges form a system of submarine mountains rising from the ocean floor and encircling the globe. Deep ocean trenches extend to great depths below the abyssal plains. These trenches are often parallel to the edges of continents or to island arcs. Island arcs rise above sea-level to form chains of volcanic islands. Also above sea-level, mountain belts occur as linear regions which may be on the edges of continents or in their interiors. (*105 words*)

More advice on how to describe diagrams in words is given in Activity 7.2

Activity 7.1

Your answer should include the following effects. We have grouped some effects together; you may have chosen some other way of organizing your notes.

Sounds: deafening, roaring, creaking and rattling

Ground motion: violent motion; aftershocks

Effect on buildings: shuddering, shaking, swaying, collapse

Effect on objects inside buildings: falling, breakage, shaking

Effect on transport: derailed trains, bent rail tracks, toppled roads

Fires

Death

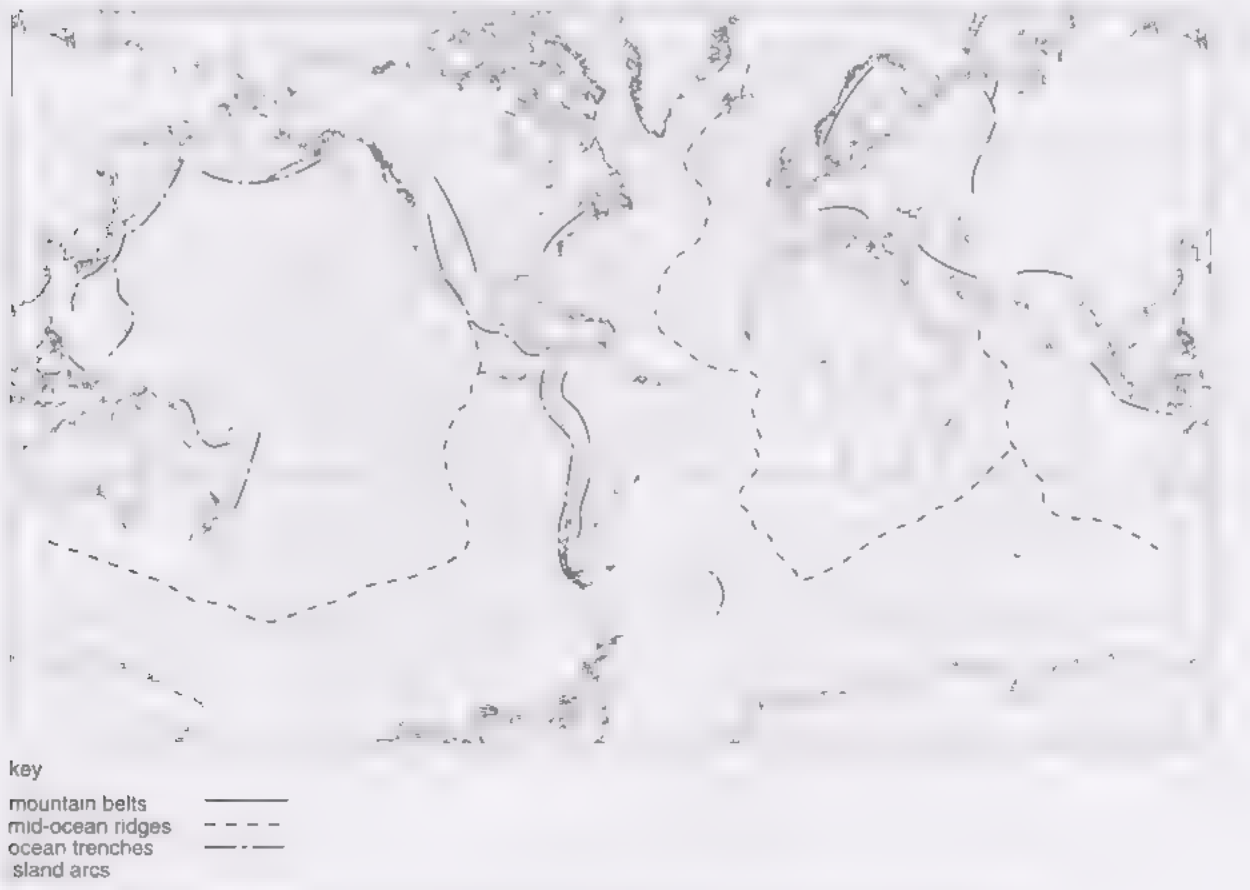


Figure 6.2.3 Completed sketch map showing mountain belts, mid-ocean ridges, ocean trenches and island arcs

Activity 7.2

(a) Earthquakes are not distributed evenly across the Earth's surface, so it does not seem sensible to describe the pattern simply as a variation from west to east across the map. The fact that earthquakes occur in distinct regions is reflected in the answer given below:

> Earthquakes are concentrated in specific regions of the Earth, and they often occur in linear belts or arcs. One belt surrounds the Pacific Ocean, including Japan, Alaska and the western coast of North, Central and South America. Another region is from south-eastern Europe through the Middle East and the Himalayan Mountains. There are also earthquakes in linear zones in the oceans.

The decision to structure the answer in this way was made after looking at Figure 7.7. If the question had asked you to look at a different map and describe the variation of something different, such as population, you would probably have ordered your answer in a different way (possibly continent by continent) so as to give the most logical answer.

(b) In this part, the planning involved looking at two very different maps and noting their different scales and projections (Try to get into the habit of looking to see if a scale has been given whenever you look at a map or a diagram, and also to put a scale on any diagrams you produce so that other people looking at them will understand what you are depicting.) Comparing Figure 7.7 with the poster leads to the following conclusions about the relationship between shallow and deep-focus earthquakes and surface features:

(i) Shallow-focus earthquakes appear to be associated with mid-ocean ridges, with mountain ranges in the interior of the continents of Europe and Asia, and with the mountains and ocean trenches that surround the Pacific Ocean

(ii) Deep-focus earthquakes appear to be associated mainly with the mountains and ocean trenches that surround the Pacific Ocean (for example, near the coast of South America, or the coast of Japan).

Activity 7.3

(a) (i) Mountains and ocean trenches surrounding the Pacific Ocean: magnitude 8.0–8.9.

(ii) Mountain belts in Europe: magnitude 7.0–7.9; mountain belts in Asia: magnitude 8.0–8.9.

(iii) Mid-ocean ridges: magnitude 7.0–7.9. (In fact the maximum magnitude at mid-ocean ridges is 7.5, but this is not shown on Figure 7.7.)

(b) See Table 7.3.2.

In Sections 13 and 14 you will find out how these observations about the distribution of seismic zones on the Earth can be explained by plate tectonics.

Table 7.3.2 Completed version of Table 7.3.1 The depths and sizes of earthquakes at different locations

	Mountains and ocean trenches surrounding the Pacific	Mountain belts		Mid-ocean ridges
		Europe	Asia	
depth (shallow-focus, intermediate-focus, or deep-focus)	[illegible] and deep-focus	[illegible] a few intermediate	[illegible] a few intermediate	shallow-focus
largest magnitude (up to magnitude 7.9, or over magnitude 8.0)	over 8.0	up to 7.9	over 8.0	up to 7.9

Table 8.1.3 Completed version of Table 8.1.2 A summary of common volcanic eruption styles, their causes and their effects

Eruption style	Description	Examples of volcanoes with this type of eruption	Causes and processes	Effects and hazards
Lava flow	relatively slow moving (up to a few m s^{-1}) streams of molten magma	[illegible] Etna	[illegible] fire fountains, and welling out of magma from a vent	can cover wide areas, can destroy land and buildings
eruption column	[illegible] reaching between a few km and tens of km into atmosphere	Mt St Helens, Galunggung, Pinatubo, El Chichon	[illegible] entrained air, produced in an explosive eruption	hazard to aircraft; deposits a thick blanket of ash over wide areas
pyroclastic flow	denser-than-air mixtures of [illegible] which travel at high speed (up to 100 m s^{-1}) down slopes and across the ground	Mt St Helens, Unzen, Augustine, Soufriere Hills	collapse and fragmentation of lava and spilling out of denser-than-air mixture from a vent during an explosive eruption	highly destructive; deposits pyroclasts over the area traversed by the pyroclastic flow

Activity 8.1

Task 1

See Table 8.1.3.

Task 2

Three suitable sketches are given in Figure 8.1.2.

SGSG Chapter 3, Section 2.1 identifies three types of diagram:

1 Pictures or pictorial diagrams that attempt to represent the essential features of a part of reality.
2 Diagrams that try to describe inter-relationships between ideas, processes or concepts using words, lines and various blobs or boxes
3 Mathematical diagrams, such as charts and graphs, that are mainly designed to convey mathematical relationships.

You have met diagrams of all three types in the earlier blocks, and have had some practice at drawing them for yourself. Here we asked you to draw a diagram of the first type. Diagrams like this are frequently used to clarify a piece of text, and you will be asked to include diagrams of this sort in TMA questions to clarify your written answers. When producing a diagram you should

- Keep it simple; don't include details that are irrelevant to the purpose for which the diagram is included; aim for clarity rather than a great work of art
- Label the important features that are relevant to the purpose for which the diagram is included. it is useful to read through the accompanying text after producing the diagram, while asking yourself whether you have labelled all of the features that are referred to
- Include a caption that indicates what the diagram shows; if you have a number of diagrams you may need to label them with numbers and or letters so that you can easily refer a reader to the appropriate diagram.

You might like to look back at your answer to Activity 4.6 in Block 1 to remind yourself of features that you considered to be important in illustrations.

Summary

The eruptions shown in the DVD-video fell into three styles of activity: lava flows; eruptions that produce pyroclastic fall deposits; and pyroclastic flows. Explosive eruptions produce a mixture of hot gas and pyroclasts, but the behaviour of the erupted mixture depends on whether its density is less than or greater than that of the atmosphere (Figure 8.1.2). In the case where the mixture is less dense than the atmosphere, the mixture rises high into the atmosphere, entraining cold air, and eventually spreads out in an umbrella cloud. Pyroclasts fall out of the umbrella cloud, blanketing the land in a layer of pumice, ash and other volcanic rock debris (a pyroclastic fall deposit) which may be many metres thick near the volcano and cover many thousands of square kilometres. The extremely widespread distribution of the pyroclastic material reflects the facts that the umbrella cloud spreads out to great distances from the volcano and is also carried downwind. In the case where the erupted mixture is denser than the atmosphere, the mixture fountains out of the volcano and flows at great speed down the side of the volcano as a pyroclastic flow. This fast-moving mixture of hot gas and pyroclasts is highly destructive, and it covers the ground over which it flows with a deposit of pumice and ash. Thus, the hazards posed by an eruption, and the nature of the resulting rock deposit, depend on the style of the eruption.

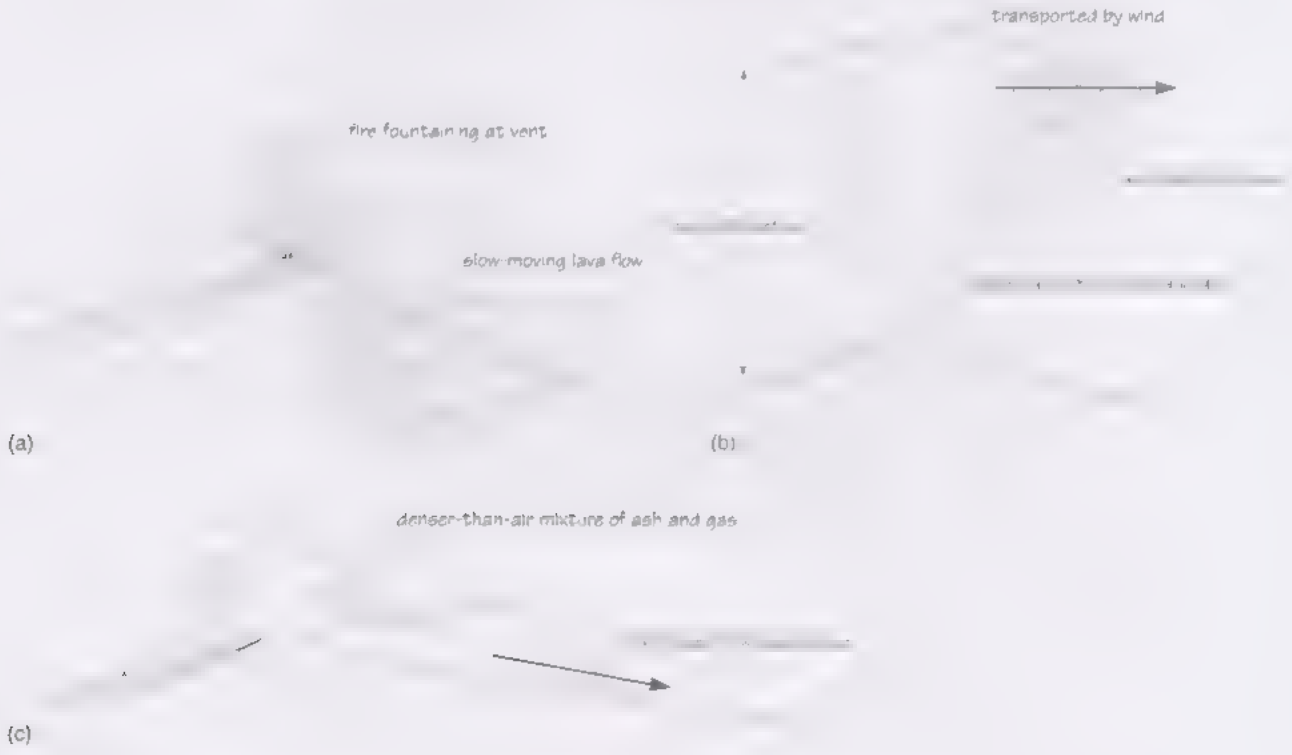


Figure 8.1.2 Three eruption styles. (a) lava flow, (b) eruption column, and (c) pyroclastic flow.

Activity 9.1

There are no comments on Tasks 1–5.

Task 6

Your notes on Specimen 4 should contain some or all of the following points:

Overall grey colour — both dark and light-coloured minerals — crystalline texture — individual crystals 0.5–5 mm in size — contains many small shiny flakes of a silvery-coloured mineral (sometimes rusty-brown) — some round grains of a reddish, glassy mineral — mineral crystals arranged in alternating layers of darker and lighter materials — layers wavy or contorted, less than 1 mm to about 3 mm thick .

(*Note*: The specimens vary slightly, the colour banding is more pronounced in some than others.)

Task 7

Your notes on Specimen 5 should contain the following points:

Dark-coloured — crystalline texture — mainly dark, fine-grained material, individual grains barely visible with hand lens — numerous small white crystals, up to about 4 mm in size — also some black blocky crystals, up to 8 mm — brown or orange staining on some surfaces.

(*Note*: The specimens vary slightly; most specimens will have some brown or orange staining.)

Although this rock, like Specimen 4, has a crystalline texture, it does not show any layered alignment of crystals. This suggests that Specimen 5 did not form under pressure by metamorphism.

Task 8

1 White crystals — up to 1 cm long, 0.5 cm wide.

2 Grey, glassy crystals — up to 1 cm across.

3 Dark crystals — typically 1–5 mm across.

Summary

Table 9.1.2 is a completed version of Table 9.1.1 and summarizes the information on the five rock specimens. Note that the largest grains in a particular rock type vary from sample to sample, particularly if the rock contains rare large crystals.

In completing this activity you have developed skills of observation, description and interpretation. For the first three specimens you made simple observations and answered questions. For Specimens 4 and 5 you made observations and described what you saw. For Specimen 6 you drew on the knowledge gained in examining the earlier specimens to make your own interpretation of the origins of the specimen. Well done!

Table 9.1.2 Completed version of Table 9.1.1. Observations and interpretation of rock specimens.

Specimen number	Texture	Colour(s)	Typical grain size(s)	Rock type (metamorphic, sedimentary or igneous)	Process of formation	Rock name	Additional comments
2	fragmental	creamy white	1 to 4 mm	sedimentary	accumulation of sand grains	sandstone	grains are mostly quartz
3	fragmental	dark grey with pale fragments	fossils up to 1 cm long	sedimentary	accumulation of fossil fragments and mud on sea bed	limestone	contains fossils, dissolves in acid
4	crystalline	dark grey with silvery-brown crystals	0.5 to 5 mm	metamorphic	recrystallization of rock in solid state at great depth under high temperature and pressure	schist	
5	crystalline	black	very fine-grained with some larger crystals, white crystals up to 4 mm long, black crystals up to 8 mm	igneous (extrusive)	rapid cooling and crystallization of magma at Earth's surface	basalt	contains gas bubbles
6	crystalline	pale, but with some black crystals	occasionally up to 2 cm long in some samples, but mostly under 1 cm	igneous (intrusive)	slow cooling and crystallization of magma underground	granite	

Table 9.2.2 Completed version of Table 9.2.1. Summary of rock features.

	Sedimentary	Metamorphic	Extrusive igneous	Intrusive igneous
texture (fragmental or crystalline)	fragmental	crystalline	crystalline	crystalline
for rocks with crystalline texture, do the crystals have random orientations or are they arranged in layers?	—	layers	random	random
can fossils be present?	yes	no	no	no
for igneous rocks, describe the grain size and how it relates to cooling rate	—	—	small crystal size, indicates rapid cooling	large crystal size, indicates slow cooling

Activity 9.2

See Table 9.2.2 (*above*).

(Although the text in Section 9 did not explicitly state that fossils are not found in metamorphic and igneous rocks, you may have worked out that fossils are unlikely to be formed or preserved by the processes that yield metamorphic and igneous rocks.)

Activity 10.1

Drilling indicates that the surface rock types extend to a depth of at least 12 km on the continents, and at least 2 km under the oceans.

Density measurements indicate that the Earth's interior includes materials with higher densities than surface rocks.

Since some volcanoes erupt magmas containing lumps of peridotite, this rock must be one component of the Earth's interior.

Activity 10.2

Summary of the DVD-multimedia section 'Seismic waves'

There are two types of body wave, **P waves** and **S waves**. P waves are compressional waves, and S waves are transverse waves. P waves travel faster than S waves. S waves cannot travel through a liquid. There are two types of surface wave, **Love waves** and **Rayleigh waves**. Love waves move the ground surface horizontally, and Rayleigh waves move the ground both horizontally and vertically. Surface waves travel more slowly than body waves; Rayleigh waves are the slower of the two types of surface wave.

Activity 10.3

Summary of the DVD-multimedia section 'Travel time graphs'

Beyond distances of a few hundred kilometres, the travel time graph shows an additional P wave, corresponding to waves that have travelled at a higher speed in a lower layer of the Earth, called the **mantle**. The upper layer, where speeds are lower, is called the **crust**. Seismic waves change direction as they travel from the crust into the mantle, this behaviour of waves is called **refraction**. The boundary between the crust and mantle is called the **Mohorovičić discontinuity**, usually abbreviated to the **Moho**.

P-wave speeds vary between different crustal rock types. An increase in the P-wave speed will result in a decrease in the gradient of a travel time graph, and vice versa. Crustal and mantle P-wave speeds, and the depth of the Moho, can be calculated from a travel time graph.

Activity 10.4

See Table 10.4.2.

You will learn later (Section 14.1.1) that the basalt in the oceanic crust is overlain by a layer of sediment, and underlain by a rock called gabbro.

Table 10.4.2 Completed version of Table 10.4.1. Characteristics of oceanic crust and continental crust.

	Oceanic crust	Continental crust
thickness	7 km[a]	20–80 km, average 35 km[a]
mean P-wave speed	7 km s^{-1}[a]	6 km s^{-1}[a]
density	about 3.0×10^3 kg m^{-3}[b]	about 2.8×10^3 kg m^{-3}[b]
rock types	basalt[b]	sedimentary (e.g. sandstone, limestone) and metamorphic rocks, granite and some other igneous rocks[c]

Notes on sources of information: *a* from Figure 10.10 in the book and the paragraph preceding it; *b* from Section 6.3; *c* from Sections 6.3 and 9.5.

Activity 10.5

Summary of the DVD-multimedia sections 'Modelling the mantle' and 'Down to the centre'

The seismic wave speed in the mantle suggests that the mantle is formed of peridotite. Travel time graphs for greater distances are curved due to changes in the speed and direction of seismic waves with depth, and to the Earth's curvature. Travel time curves for greater distances show shadow zones. The **P-wave shadow zone** is caused by refraction at the **seismic discontinuity** that marks the boundary between the mantle and the central part of the Earth, called the **core**, about 2 900 km below the surface. The **S-wave shadow zone** occurs because the core blocks the passage of S waves. For this to happen, the outer part of the core (at least) must be in a liquid state.

Activity 10.6

(a) In an ideal world you would be able to study and understand perfectly all of the course material in the suggested time, and as scheduled in the Study Calendar. But like most of us, you don't live in such a world, and you will have to make compromises. What is important is that you keep to the schedule in the Study Calendar as closely as possible, since you will need to adhere to the deadlines for submission of the TMAs. So if you are behind schedule (and few students are not in this position at some time or other) then you have to find extra time or focus on the most important parts of the course material. This is something that you may want to talk through with your tutor.

(b) If you are spending too much time on the DVD-multimedia activities it may be because you are not focusing on their main aims. You may be using a trial-and-error approach (that's OK for computer games, but won't get you very far in learning!) rather than thinking carefully about what you are doing and why you are doing it. A more disciplined approach will be particularly important in the next DVD-multimedia activity (in Section 12) — an exploration of a mid-ocean ridge — because there are a lot of resources to explore and you will therefore need to be selective in your choice of what you look at. This will clearly be much easier to do if you keep in mind the main aims of a particular activity.

Making written notes of the main points of DVD-multimedia activities is the simplest way of producing a record of what you have done, and it has the advantage that you can see what is on the screen while you are making your notes. However, you may prefer to use your computer to record your notes, and since the computer can run several applications at the same time this is fairly straightforward. You just need to have your word-processing package, or the Windows WordPad accessory, running at the same time as the CD-ROM activity. If you have a large screen, you may be able to see both applications at the same time, but if the DVD-multimedia application fills your screen, you will need to switch between the applications using the ALT + TAB key combination.

As when studying the book, you have to compromise between very detailed notes that are time-consuming to make and that take as long to read as the material that they are based on, and very skimpy or cryptic notes that leave you wondering what you meant when you wrote them. You may find that it is a good idea to take fairly detailed notes as you work through the CD-ROM activity, and then to write a brief summary (also in note form) of the main points in the activity once you have reached the end.

(c) You will get a lot more practice with diagrams and tables, and will develop further skills associated with using and producing them, as you study the second half of this block. Also *SGSG* Chapter 3 is about 'working with diagrams' and you may find it useful to dip into that at this point. If you are unsure about particular aspects of diagrams and tables, then you could revisit questions or activities that are related to them, or you might discuss your uncertainties with other students or your tutor. But as you work through the block, continue to bear in mind the objectives related to diagrams and tables that we pointed out in Activity 1.1.

Activity 11.1

See Table 11.1.2.

Table 11.1.2 Completed version of Table 11.1.1. Locations of fossils across the world at 280 Ma and 260 Ma

Age Ma	Fossils	Locations
260	*Glossopteris*	South America, Africa, Antarctica, India and Australia
260	*Mesosaurus*	South America and Africa
280	*Edaphosaurus*	Europe and North America

(a) The fact that *Glossopteris* not only occurs on the same continents as *Mesosaurus*, but also on numerous others, suggests that continents other than just South America and Africa were joined at 260 Ma. It supports the hypothesis that continental drift was active elsewhere in the world too.

(b) The new evidence from the distribution of *Glossopteris* fossils suggests that India has moved considerable distances over the last 260 Ma. It appears to have travelled from the Southern Hemisphere across the Equator to the Northern Hemisphere.

(c) Based on fossil occurrences, the continents of South America, Africa, Antarctica, Australia, and India appear to have been joined around 260 Ma ago. This coincides with the dates Wegener proposed for Pangaea. Also, North America and Europe appear to have been joined around 280 Ma ago, and Wegener had evidence to suggest that they also belonged to Pangaea, thereby supporting his idea of a supercontinent.

Activity 11.2

(a) The changing values of latitude in Figure 11.5 indicate that the positions of India and Africa have changed over the last 300 Ma.

(b) The two continents followed the same northward route between 300 and 200 Ma. (Strictly speaking, we have no information about how their palaeolongitudes changed during this period, so their east–west separation *may* have changed.)

(c) The two landmasses started to diverge from each other 200 Ma ago, and thereafter travelled separately.

(d) Here is our sample answer.

> Between 300 Ma and 200 Ma ago the two continents were more or less at the same latitude and appeared to travel together northwards. Between 200 Ma and 150 Ma ago both continents were moving southwards, but their palaeolatitude paths started to diverge. This indicates that they were beginning to travel independently of each other, i.e. Pangaea was dividing to produce two new continents. Between 150 Ma and 100 Ma ago India continued to travel southwards, but Africa travelled northwards. Since 100 Ma ago both continents have moved northwards, but India travelled a lot farther — over 50° of latitude compared with less than 10° for Africa. In other words, during this time India moved a lot faster than Africa. In addition, the southern tip of India 'overtook' the Mozambique area of Africa about 80 Ma ago, so that it became the more northerly landmass India appears to have slowed down about 50 Ma ago, as indicated by the smaller gradient of the graph. (*161 words*)

All of the information about the positions and motion of India and Africa in this paragraph was taken from Figure 11.5, and we have tried to link each piece of evidence from the graph with a description of their motion. The slowing down of India's motion in the last 50 Ma is due to the fact that India crashed into Asia

(e) The graph supports the hypothesis of continental drift, since it clearly shows that Africa and India have drifted over considerable latitudes, and therefore over great distances too, since 300 Ma ago.

Activity 12.1

Task 1

Active black smoker: This term is applied to a flow of hot water and fine black mineral particles, rich in metals and sulfur, and the chimney of mineral deposits through which the flow passes. The 'smoke' particles are produced when hydrothermal fluid escapes from the crust and mixes with cold seawater

Fissure: This is a long narrow cleft in the rocks of the ocean floor, running parallel with the length of the ridge. It is caused by stretching apart of the crust at the ridge.

Scarp face: This is the face of long cliffs running parallel with the length of the ridge, formed by stretching of the ocean crust at the ridge.

Hydrothermal mound: These are areas up to several hundred metres across composed of mineral deposits produced by hydrothermal fluids that have flowed up through weaknesses in the crust and mixed with seawater; black smokers are active in these areas. A diversity of organisms such as fish, bacteria, mussels, shrimps and anemones inhabit active hydrothermal areas. These organisms ultimately rely on the hot water and sulfur in the hydrothermal fluids for their energy, totally unlike more familiar organisms that depend on energy from the Sun for photosynthesis

Derelict hydrothermal area: This is a region where hydrothermal activity has ceased. The hydrothermal minerals and rocks are chemically decomposing by reacting with cold seawater.

Lava flow: Basalt magma erupts onto the ocean floor at mid-ocean ridges, forming lava flows.

Sediment: Fine carbonate mud rains onto the ocean floor from dead micro-organisms that lived in the surface ocean. The thickness of the layer of sediment indicates how long ago the underlying ocean floor was formed.

Task 2

The evidence for the processes involved in sea-floor spreading is summarized in Table 12.1.2.

Activity 12.2

The completed passage summarizing the results is as follows:

> In this study, marine magnetic anomalies from 7 traverses across the Southeast Indian Ridge were used to find the average rate of sea-floor spreading during the last 4 Ma.
>
> The results show variation from a minimum spreading rate of 56 mm y^{-1} to a maximum rate of 76 mm y^{-1}. (You may have used the unit km Ma^{-1}; if so, you should have used the same numerical values as those shown here.)
>
> Moving from northwest to southeast along the Ridge, the sea-floor spreading rate increases, reaching a maximum of about 80 mm y^{-1} at a point between western Australia and Antarctica near 46° S 118° E, before decreasing

Activity 13.1

See Table 13.1.2.

Table 12.1.2 Completed version of Table 12.1.1. Evidence for sea-floor spreading processes.

Name of feature	Evidence that the crust is being pulled apart on either side of a mid-ocean ridge	Evidence that hot material underlies the mid-ocean ridge
fissures running parallel to the length of the ridge	formed by faulting of the crust when it is stretched	
scarps running parallel to the length of the ridge	formed by faulting of the crust when it is stretched	
chimneys, hydrothermal mounds and black smokers		discharge of hot mineral-rich fluids
eruption of lava flows onto the ocean floor		molten magma under the ridge
layer of sediment cover	becomes thicker farther from the ridge, indicating that young crust is produced at the ridge and crust further from the ridge is older	

Table 13.1.2 Completed version of Table 13.1.1. The characteristics of each type of plate boundary

	Divergent	Convergent	Transform fault
direction of motion of plates with respect to plate boundary	away from boundary[a]	towards boundary[a]	parallel[a]
depth of earthquake foci (shallow, intermediate, or deep)	shallow[b]	shallow, intermediate and deep[b]	shallow[b]
destruction or creation of lithosphere, or neither	creation[a]	destruction or thickening[a]	neither[a]
physical features associated with boundary	mid-ocean ridge[c]	ocean trench, island arc/mountain belt, volcanoes[c]	fault[a]

Notes on sources of information: [a] from Section 3.2; [b] from Figure 7.7 and Activity 7.2; [c] from Sections 6.2.2, 6.2.3 and 13.2 and Activity 6.2.

Activity 13.2

At the eastern plate boundary, a gap opens, indicating sea-floor spreading at a divergent plate boundary. At the western boundary, paper plate A will go under or over paper plate B; this is a convergent boundary. At the north and south boundaries the paper plates just slide past each other, and these correspond to transform faults

You may wish to use this paper-cutting technique to help you to visualize what happens in some of the other example of plate motion that you will meet in this block. This was the method that Earth scientists in the 1960s originally used to consider the implications of plate motion; scientific discoveries do not always involve elaborate equipment!

Activity 13.3

Summary of the DVD-multimedia 'Plate tectonics on a sphere'

The variation of sea-floor spreading rate along a mid-ocean ridge is a consequence of relative plate movement on a spherical Earth. The relative motion of any two plates on the Earth is a rotation about an imaginary axis that passes through the centre of the Earth. The **axis of rotation** is defined by the position of the **pole** of rotation, which is the place where the axis intersects the surface of the Earth. Each plate pair has a pole of rotation and an anti-pole.

The different types of plate boundary arise from different orientations of the plate boundary with respect to the pole of rotation. Divergent and convergent boundaries (except those where movement is oblique to the plate boundary) lie on **great circles** passing through the pole of rotation. Transform fault plate boundaries lie on **small circles** centred on the axis of rotation. The relationship between the type of plate boundary, the orientation of the boundary, the direction of motion and the pole of rotation can be illustrated by a diagram

The position of the pole of rotation for two plates can be determined from sea-floor spreading rates or transform fault directions. Conversely, the direction of relative motion and the type of boundary between two plates can be determined if the pole of rotation is known.

Activity 14.1

Here is a specimen answer.

> Convergent plate boundaries come in three varieties: oceanic lithosphere converging with oceanic lithosphere, continental lithosphere converging with oceanic lithosphere, and continental lithosphere converging with continental lithosphere.
>
> In the two cases where oceanic lithosphere is involved, subduction occurs and this produces a deep oceanic trench along the plate boundary. Subduction also produces a row of volcanoes about 200 km away from the plate boundary, on top of the plate that does not get subducted. In contrast, where two pieces of continental lithosphere converge, subduction does not take place. Instead, a mountain belt is produced by the collision of the continents. The mountain belt lies along the plate boundary.
>
> Earthquakes occur at all types of convergent plate boundary, but the distribution of earthquake foci depends on the types of lithosphere involved. Where subduction occurs, shallow-, intermediate- and deep-focus earthquakes are generated. In these cases, earthquakes occur at increasing depth away from the plate boundary, defining a Wadati–Benioff zone, which indicates the position of subducted oceanic lithosphere. However, at continental collision zones, earthquakes are confined to shallow depths and are distributed broadly across the zone of collision.
>
> Volcanoes are associated with convergent plate boundaries only where at least one plate is oceanic. They are not found where both plates have continental lithosphere at the boundary. (*213 words*)

Note that this account starts by clearly stating what the three types of boundary are, and then goes on to discuss three features of plate boundaries (topography, earthquakes and volcanic activity) in turn and in separate paragraphs

Activity 14.2

See Table 14.2.2.

Table 14.2.2 Completed version of Table 14.2.1 Features of plate tectonics near the west coast of North America

Boundary on Figure 14.12b	Name of plate boundary on Figure 14.12c	Relative plate motion	Associated phenomena
AB	Aleutian Trench	subduction of Pacific Plate beneath North American Plate	Alaskan volcanic arc, including Katmai (iv) Also Augustine volcano (featured in 'Volcanoes' video, Activity 8.1)
			Wadati–Benioff zone responsible for the 1964 Alaska earthquake (iii)
BC	Queen Charlotte Transform Fault	Pacific Plate slides north past North American Plate	zone of shallow-focus earthquakes
CD	Juan de Fuca Ridge	sea-floor spreading constructs Juan de Fuca Plate and part of Pacific Plate	first marine magnetic anomaly pattern mapped across a mid-ocean ridge (ii)
CE	Cascadia Subduction Zone	Subduction of Juan de Fuca Plate beneath North American Plate	Cascade Volcanic Arc, including Mount Saint Helens (i) (featured in 'Volcanoes' video)
DE	Mendocino Transform Fault	Juan de Fuca Plate slides past Pacific Plate	zone of shallow-focus earthquakes
EF	San Andreas Fault	Pacific Plate slides north past North American Plate	zone of shallow-focus earthquakes Poses seismic hazard to San Francisco, Los Angeles and other Californian settlements, site of seismic research (v)
FG	Part of sea-floor spreading system connected by transform faults to the East Pacific Rise	sea-floor spreading involving Pacific and North American Plates	bacterial mats, clams and tube worms found associated with hydrothermal vents in the Gulf of California (Activity 12.1)

Activity 16.1

Summary of the DVD-multimedia 'Plate motion in the past and future'

The positions of plates in the past can be reconstructed from data on continental fit, occurrence of fossils, ancient climates and palaeomagnetism. Marine magnetic anomalies are the most useful data, but magnetic anomaly reconstructions are only available for the last 140 Ma or so. Continental reconstructions can be made for much earlier times. Palaeocoastline and palaeotopography reconstructions are also useful guides to past plate movement. Plate movement is continuously changing the appearance of the Earth's surface as the continents move through cycles of grouping into one or more supercontinents, and then split apart. During the last 400 Ma, plate motion has created and destroyed oceans, and created and split supercontinents. Some countries or continents have moved large distances, changing latitude and thus climate. The UK, for example, has moved from the Southern Hemisphere, through the tropics, to its present northern latitude. Continents can also change in size and orientation through time.

Predictions of future plate motion use present plate motion as a starting point to predict what may happen to plates, continents and oceans. Predictions are just possibilities — the best estimates that can be made at the moment. We predict that, in the next 100 Ma, the Red Sea may close and Australia may move north and collide with Japan.

Activity 17.1

(a) Following weathering and erosion of the exposed sedimentary rock, mineral grains are transported by water, air or ice to a site of deposition. Once deposited they can become compacted and cemented together to form a sedimentary rock. Deep burial and recrystallization of the sedimentary rock will then yield a metamorphic rock.

(b) The intrusive rock may become deeply buried and recrystallized to form a metamorphic rock. Alternatively, the intrusive rock may become exposed at the Earth's surface if erosion removes the overlying rocks. It may then be weathered and eroded to form sediments which are then turned into a metamorphic rock by following the same path as in (a).

(c) The only way for an atom to escape from the mantle is if it gets incorporated into a magma which then rises towards the surface. Thereafter, the magma could form a volcanic rock on the surface. If this undergoes weathering and erosion, then it can become a sedimentary rock. Alternatively, if the magma solidifies underground, as an intrusive igneous rock, then it will have to be uplifted and exposed by erosion before the process of forming a sedimentary rock can proceed. Other alternatives are that the intrusive rock could be metamorphosed before being exposed at the surface and eroded, or the metamorphic rock could be melted to produce another magma which could then embark on any of the previous paths before ending up as a sedimentary rock. A further possibility is if the atom in question was erupted as part of a volcanic gas. In this case, the atom could end up in a chemical precipitate or in biological material that becomes incorporated into sediment.

Activity 18.1

(a) Managing study time

While studying the first three blocks of the course, you should have learned a range of skills connected with forward planning, prioritizing, reviewing work schedules, time management, coping with the unexpected, and contingency planning. We shall not provide any further advice about planning, and in the remainder of the course you will need to put into practice what you have learned already about managing your studies. You may find that it is helpful to continue to make formal study plans for each block, or you may decide that it is sufficient to use the study plan on the

bookmark for each block for guidance and as something against which you can monitor your progress.

(b) Effective learning

Here are one student's thoughts about studying the 'Volcanoes' DVD-video

> I took the advice in the notes and watched it once through first, without stopping. I just made a couple of brief notes during that run through, but it gave me a good idea of the different types of eruption. Then I checked again on the tasks to find out what information I needed from the DVD-video — types of eruption, examples, causes and effects. Since there was a printed table, I thought I might as well use that for my notes, but I made them in pencil so I could modify them (and I was glad I did this!). Then I just went through all of the DVD-video again — stopped it after each eruption to make notes. At the end I rubbed out a few bits of the table and rewrote them. I thought the table was a good way of summarizing and classifying lots of information. Next DVD-video I guess I'll try the same technique of going through the whole thing to get an overview and then watching again in more detail while making notes.

You may have used a different approach; some students prefer to just go through once, stopping to replay various bits. The important thing is to take control of the DVD player, and to pause and replay any parts that are not clear.

You have now studied a range of different styles of DVD-multimedia activities. If you are still finding it difficult to learn from them, you might find it helpful to look again at the notes that accompanied the first activity, Activity 8.5 in the Block 2 Study File. This is another area where you may find it useful to exchange ideas with other students and your tutor; you are all likely to be new to this mode of study, and you are all developing new learning strategies.

Here are some reflections from a student about learning from the DVD-multimedia activities

> At first I was a bit apprehensive about all this high-tech learning, and thought I needed to note down practically everything — I guess I thought that the information would all disappear when I moved on to the next screen. I ended up with pages of notes! But when I got a bit more familiar with the computer, I realized that it only took a few seconds to go back and check on something I was unsure about, and if I wanted to check something later it only took a minute to switch on the computer and find what I was after. Once you have been through the program it's quite easy to go through it again — so my notes are now more of a framework of the main points and a guide to what is in each section. I look at these when I've finished the activity, and make sure that they are a comprehensible summary — a couple of times I've realized at this stage that I don't understand something, so I've gone back to a bit and checked it out again.
>
> Most of the DVD activities seem to be a bit like a book — you start at the beginning and go through the sections in order. The ones that were harder were the carbon cycle in Block 2 and the submarine trip. I could have spent hours more on each of them (I did spend too long on the carbon cycle), but for the submarine I knew I was pushed for time and only looked at the highlighted DVD-videos and didn't go to the Pacific. I'll probably go back to this if I have a bit of time to spare (wishful thinking perhaps).

(c) Skills development

Your general advice to yourself about reading diagrams might be something like this:

- First get an overall impression of the diagram (– is it a map, a graph, a drawing?)
- Then read the caption and, if it's a graph, the labelling on the axes
- Check any scales. Check any key, to see what the symbols mean
- Then look carefully at each part in turn, including any labelling, and look at how the parts are related to each other.
- Ask why it has been included — what is the key information that it is there to convey?

Having a general framework like this to work from can make it easier to exercise a particular skill, like reading diagrams in this case. We are not suggesting that you slavishly follow the steps, one by one, in every case, but appreciating what steps are involved does help you to develop the skill

The general process you have used here should help you to become aware of skills you are using, and allow you to develop these skills consciously. Note that the process involves:

- Selecting an example of a task where a particular skill is used
- Describing specifically what you did in that task.
- Describing in general terms, the kind of thing you did This is done by taking out the specifics, as in the bullet-point list above.

The next steps in refining the skill would be to test this general description to see if it works for you in other similar tasks (reading other diagrams) and, if necessary, modifying your general description in light of this new experience

This process involves reflection, and it is a key to improving skills. It allows you to become more aware of the skills you are using, and this puts you in a position to make any changes to your way of working that you think are necessary. Of course, this is the same sort of process that you have used when reflecting about the effectiveness of your learning in other activities in this block and in previous blocks.

Objectives for Block 3

The objectives state what you should understand and what you should be able to do after studying the block.

The numbers of questions and activities that test each objective are given in italics. In the margin next to some objectives are references to *The Sciences Good Study Guide (SGSG)*, giving the chapter: section number or Maths Help (MH) number, or to DVD material, where you can find additional support.

Science content

1 Explain the meaning of, and use correctly, all of the terms printed in **bold** in the text.

2 Outline the main features of the Milky Way Galaxy and its members, such as the stars. (*Questions 2.1– 2.3, 3.2 and 3.6; Activities 3.1 and 3.2*)

3 State and apply Newton's first and second laws of motion. (*Questions 4.1–4.7*)

4 Explain qualitatively how gravitational forces determine the motion of bodies within the Solar System and within the Galaxy. (*Questions 4.8 and 4.9*)

5 Describe the layout of the Solar System and the nature of the bodies that it comprises. (*Questions 2.1, 2.3 and 5.1–5.5; Activity 5.1*)

6 Outline the temperature variation in the oceans, account for ocean currents, and describe atmosphere/ocean interactions. (*Questions 6.1 and 6.2*)

7 Describe the topography of the continents and the oceans, using maps and cross-sections. (*Questions 6.3–6.5; Activities 6.2 and 6.3*)

8 Recognize the effects of earthquakes (*Question 7.1; Activity 7.1*), explain why they occur and describe where they occur (*Activity 7.2*), and explain how the sizes of earthquakes are specified on the Richter scale. (*Question 7.2; Activity 7.3*)

9 Describe the distribution of volcanoes on the Earth, classify their eruptions in terms of three characteristic styles, and relate these styles to the processes involved. (*Question 8.1; Activity 8.1*)

10 Describe how igneous, sedimentary and metamorphic rocks are formed, and relate the processes involved to features observed in hand specimens of rocks. (*Activities 9.1 and 9.2*)

11 Distinguish the different properties of P waves, S waves, Love waves and Rayleigh waves (*Activity 10.2*), and describe qualitatively how seismic waves are refracted as they pass through regions of the Earth where their speed changes. (*Activities 10.3 and 10.5*)

12 Read and interpret travel time graphs for seismic waves. (*Activities 10.3 and 10.5*)

13 Compare and contrast the features and properties of oceanic and continental crust. (*Activity 10.4*)

14 Describe how density generally increases inside the Earth, and outline the basic structure and composition of the Earth. (*Question 10.2; Activity 10.5*)

15 Outline evidence from fossils, palaeoclimate studies and palaeomagnetism that supports the continental drift theory. (*Question 11.1; Activities 11.1 and 11.2*)

16 Describe the process of sea-floor spreading and explain how marine magnetic anomalies and the geomagnetic polarity time-scale are used to calculate sea-floor spreading rates. (*Question 12.1; Activity 12.2*)

17 Distinguish the different properties of the lithosphere and asthenosphere. (*Question 13.1*)

18 Describe the characteristic features and processes associated with the different types of plate boundaries. (*Questions 13.3 and 14.1; Activities 12.1, 13.1–13.3, 14.1 and 14.2*)

19 Explain how the relative motion between two plates can be described in terms of a rotation about an axis through the Earth's centre, and how this axis can be specified by the position of its pole. (*Activity 13.3*)

20 Describe how the relative speeds of plates are measured, and calculate such speeds from appropriate data. (*Questions 13.4–13.6; Activity 12.2*)

21 Describe how the absolute speeds of plates are measured and calculate such speeds from appropriate data. (*Questions 15.1 and 15.2*)

22 Describe possible mechanisms for plate motion. (*Question 15.3*)

23 Describe the life cycle of ocean basins and how the continents have grown with time, and explain the reasons for the differing ages of oceanic and continental crust. (*Questions 16.1 and 16.2*)

24 Outline the evidence used to reconstruct past positions of plates and continents, and describe past and possible future plate motion. (*Questions 16.3–16.5; Activity 16.1*)

25 Describe the main processes in the rock cycle, and recognize its interaction with the water cycle, the atmosphere, the carbon cycle and life. (*Questions 17.1 and 18.2; Activity 17.1*)

26 Describe ways in which the biosphere has influenced the Earth's atmosphere, lithosphere, water cycle, and other chemical cycles. (*Questions 18.1–18.3*)

Science skills

SGSG 8: 2 27 Use a classification scheme to group observations, objects or processes with similar characteristics (planets, volcanoes, rocks, seismic waves, plate boundaries). (*Activities 5.1, 8.1, 9.1, 10.2 and 13.1*)

SGSG 8: 3 28 Explain the nature of a hypothesis and its role in the scientific process; use multiple lines of evidence to test a hypothesis, and modify the hypothesis if necessary. (*Questions 11.1 and 11.2; Activities 11.1 and 11.2*)

SGSG MH10 29 Plot a graph to represent a given set of data, with appropriate axes, scales, labelling and title. (*Activities 10.3 and 12.2*)

SGSG MH10 30 Draw the best-fit straight line through a graph, calculate the gradient of a straight-line graph, and specify the unit associated with the gradient. (*Question 15.1; Activities 10.3 and 12.2*)

SGSG 8: 2; 9: 2.2 31 Make and record observations of geological specimens, and use these observations to deduce the origins of the specimens and to classify them. (*Activity 9.1*)

Communicating science skills

SGSG 2: 5.2; 3: 3.1, 4 32 Summarize information from text, diagrams, DVD-video activities, DVD-multimedia activities and practical work in writing, in a table, or in a diagram. (*Questions 6.2–6.4 and 7.2; Activities 5.1, 6.3, 7.1, 7.2, 7.3, 8.1, 9.1, 9.2, 10.1, 10.4, 11.1, 11.2, 12.1, 12.2, 13.1, 14.2 and 17.1*)

SGSG 3: 3.2 33 Read information from maps, and annotate maps to display information about various features. (*Questions 6.5 and 8.1; Activities 6.2, 6.3, 7.2, 7.3 , 11.1 and 14.2*)

SGSG 3: 3.2; MH10 34 Read information from graphs of various types including those using a powers of ten scale. (*Questions 6.2 and 15.1; Activities 10.3, 10.5, 11.2 and 12.2*)

SGSG 3: 3.1, 4.2 35 Produce simple diagrams to illustrate the main features of objects or phenomena. (*Activities 6.2 and 8.1*)

SGSG 9: 5.2 36 Write an account that compares and contrasts a number of items in order to bring out their similarities and differences. (*Activity 14.1*)

Mathematical skills

37	State and use correctly the SI units of speed, acceleration, force, density. (*Various numbered questions and activities that involve calculations.*)	*SGSG* 5: 4.1
38	Calculate the sizes of features in a scale model or diagram from the sizes of the corresponding features in the real world, or vice versa, and determine the scale of a model. (*Activity 3.1*)	
39	Use suitable symbols to represent physical quantities. (*Question 4.7*)	*SGSG* MH9
40	Rearrange and solve equations, either in words or symbols, of the form $a = b \times c$. (*Questions 3.4, 3.5, 4.6 and 4.7*)	*SGSG* MH9; Block 3 DVD 'Algebraic manipulation'
41	Perform calculations involving powers of ten. (*Questions 3.1, 4.6, 5.3 and 7.2; Activity 3.1*)	*SGSG* MH8; Block 1 DVD 'Practising maths skills'
42	Work to an appropriate number of significant figures. (*Questions 3.1, 4.5, 4.6 and 5.3; Activity 3.1*)	*SGSG* MH6

Effective learning skills

43	Plan and manage the time spent on the activities, and keep appropriate records of the activities. (*Activities 1.1, 10.6 and 18.1*)	*SGSG* 1: 3
44	Review and reflect on the various study and learning techniques used, particularly those associated with diagrams and tables, and with DVD activities, and modify use of these techniques in light of experience. (*Activities 10.6 and 18.1*)	*SGSG* 1: 4.1; 3: 3.2; 6: 3.2, 5

Appendix What to do if you are short of time

Many of the activities in the Study File are designed to reinforce what you have learned from other components of the block or to help you to develop good study skills. Although it is important to work through them all if you want to obtain the full benefit from your study, you may need to prioritize the activities if you find yourself running short of time. In this instance you will have to decide which ones are essential for *you* to do and which could be studied out of sequence, or even omitted without too much harm.

Although the activities form a crucial component of your skills development in *Discovering Science*, one of the elements of this development is to encourage you to take responsibility for your own learning. This brief guide to the activities in Block 3 should help you to decide for yourself whether you need to do a particular activity.

The five numbered columns in the table overleaf offer advice about each activity as follows:

1 essential that you do this activity at the particular point in Book 3 where it appears;
2 important, but there is more flexibility about when you do this activity, although you should try to complete it before moving onto the next section of Book 3;
3 may not be essential if you have some background already in the topic or skill, or have found earlier, similar activities straightforward;
4 could be left until later, or dropped altogether if you are really short of time;
5 forms a useful tool should you wish to revise at the end of the year, perhaps before undertaking another course.

The last column on the right contains additional advice about some of the activities.

A similar appendix will be found in each of the Study Files for Blocks 4 to 11. As you might expect, at this stage in the course we are suggesting that most of the activities are either essential or important. However, as you progress through the course, building up your skills base, you will probably find that is it possible to regard more of the activities as less important for you.

Block 3 Activities

Activity	Category					Comments
	1	2	3	4	5	
1.1	✓					
3.1		✓				
3.2		✓				
5.1		✓				
6.1				✓		
6.2		✓				
6.3		✓				
7.1			✓			
7.2	✓					
7.3	✓					
8.1		✓				
9.1	✓					
9.2		✓			✓	
10.1	✓					
10.2	✓					Closely linked with book
10.3	✓					Closely linked with book
10.4		✓			✓	
10.5	✓					Closely linked with book
10.6		✓				
11.1		✓				
11.2		✓				
12.1		✓				Set yourself a time limit before starting this activity and stick to it
12.2		✓				Good for getting practice with graphs; try this before Activity 13.2
13.1	✓				✓	
13.2		✓				Only you can tell if you need to do this one
13.3		✓				
14.1	✓				✓	
14.2		✓			✓	
16.1		✓				
17.1				✓		
18.1	✓					

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